# Calculation of polychlorinated biphenyl (PCB) external loads for the Potomac PCB Model

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# CALCULATION OF EXTERNAL LOADS FOR THE POTOMAC PCB MODEL

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List of Acronyms

| | |
|---|---|
| BOD | Biological oxygen demand |
| CBEMP | Chesapeake Bay Environmental Model Package |
| CBP | Chesapeake Bay Program |
| CH3D | Chesapeake Bay Hydrodynamic Model |
| DC | District of Columbia |
| DC DOE | District of Columbia Department of the Environment |
| DC WASA | District of Columbia Water and Sewer Authority |
| DOC | Dissolved organic carbon |
| DynHyd, or DH | Dynamic Hydrologic Model |
| ICPRB | Interstate Commission on the Potomac River Basin |
| LTI | Limno-Tech, Inc. |
| MD | Maryland |
| MDE | Maryland Department of the Environment |
| MWCOG | Metropolitan Washington Council of Governments |
| NSWC-Indian Head | Naval Surface Warfare Center at Indian Head |
| PC | Particulate (organic) carbon |
| PCB | Polychlorinated biphenyls |
| $PCB_{3-10}$ | Polychlorinated biphenyl homologs 3 through 10 |
| PDC | Particulate detrital carbon |
| Penta-PCB | Pentachlorobiphenyls, or homolog 5 |
| POTPCB | Potomac PCB model |
| RUSLE2 | Revised Universal Soil Loss Equation, Version 2 |
| TMDL | Total maximum daily load |
| TOC | Total organic carbon |
| USDA | U. S. Department of Agriculture |
| UOSA | Upper Occoquan Sanitation Authority Wastewater Treatment Plant |
| VA | Virginia |
| VADEQ | Virginia Department of Environmental Quality |
| WM5 | Chesapeake Bay Watershed Model, Phase 5 |
| WWTP | Waste water treatment plant |

# I. Introduction and Background

This report describes the methods used to estimate input loads of polychlorinated biphenyl (PCB) pollutants, flow, and other parameters to the Potomac PCB model, and summarizes the input load results. The Potomac PCB model (POTPCB) will be used to determine Total Maximum Daily Loads (TMDLs) of PCBs entering the tidal Potomac River.

Maryland, Virginia and the District of Columbia, the jurisdictions that share the waters of the tidal Potomac River, have placed portions of the river and some of its tidal tributaries on the 303(d) impaired waters list for elevated levels of PCBs in the tissue of fish. Pursuant to the requirements of the U.S. Clean Water Act (P.L. 92-500), Total Maximum Daily Load (TMDL) studies must be done to determine the maximum pollutant load that a water body can receive and still meet its designated uses. In 2000, a consent decree was entered into by the U.S. Environmental Protection Agency (EPA) and the U.S. District Court in which the EPA agreed to a schedule for completing TMDL studies for the impairments then on the District of Columbia's 303(d) impaired waters list. That schedule required that the PCB TMDL be completed by September 30, 2007. Maryland and Virginia are not required to complete their PCB TMDLs for the tidal Potomac River and its embayments by this date, but representatives of the three jurisdictions agreed in early 2004 to coordinate their TMDL development efforts and address all their tidal Potomac PCB impairments by September 30, 2007. The Steering Committee felt that a joint TMDL would be the most cost effective and practical solution, given the close proximity of the three jurisdictions. There was also some concern that if the jurisdictions each did a separate TMDL, using different models, assumptions, and time frames, it could create confusion among the general public, particularly with respect to PCB loads crossing state lines (see Figure 1).

The agreement to coordinate the Tidal Potomac PCB TMDL led to the creation of a PCB TMDL Steering Committee representing the District of Columbia Department of the Environment, the Maryland Department of the Environment, the Virginia Department of Environmental Quality, the U.S. Environmental Protection Agency, the Interstate Commission on the Potomac River Basin (ICPRB), Limno-Tech, Inc. (LTI), and the Metropolitan Washington Council of Governments (MWCOG). The Steering Committee is the body through which the jurisdictions resolve issues, review data and model results, and guide the TMDL to completion. ICPRB is charged with coordinating the activities of the Steering Committee, managing some monitoring contracts, collecting and analyzing data, and writing the TMDL document. LTI, under contract to the EPA, is developing the Potomac PCB model and will run the model for TMDL scenarios.

The Potomac PCB model (POTPCB) characterizes transport and fate of PCBs in the Potomac River estuary. The model is comprised of linked hydrodynamic and water quality models that simulate the transport and fate of water, carbon, and PCBs in the tidal Potomac River. The POTPCB modeling package will be described in a companion report. The focus of this report is to describe the data sources and methods used to compute the daily time series of external flows, and carbon and PCB loads that are inputs to the POTPCB model. Data sources include historical data, recently collected PCB samples, literature values, and other model output.

## II. Data Sources

This section describes how three principal data sources–the Chesapeake Bay Watershed Model, historical PCB data, and new PCB samples–were utilized to develop most of the PCB load estimates. These sources were supplemented by additional information as described in Section IV.

(1) Historical Data

An extensive effort was made to locate and acquire historical fish tissue, water column, and sediment PCB data. Sample data sets for studies performed from 1989 to 2003 were obtained from multiple government agencies and universities (Tables 2 and 3). As described in Section III(1), PCB concentrations tended to decline over time. The Steering Committee decided that for the purpose of estimating input loads, the historical data would be limited to only those samples collected from 1/1/2000 to the present. Copies of these historical data may be obtained from ICPRB. They will eventually be available on the ICPRB web page, www.potomacriver.org.

(2) PCB Data Collection in 2005-2006

New PCB samples were collected specifically for this TMDL in 2005-2006. Samples for input load calculations were collected from the effluent of 15 wastewater treatment plants, 26 tributary sites, and Chain Bridge near the Potomac River fall-line. The tributary samples were collected at locations close to the head of tide and were intended to represent the discharge from the entire tributary watershed. Samples were analyzed at one of three laboratories: the University of Maryland Chesapeake Biological Laboratory (CBL), Battelle Laboratory, or the Geochemical and the Environmental Research Group of Texas A&M University (GERG). All used Method 1668A or an equivalent methodology achieving congener specific detection limits of 10 pg/liter or less (sample specific, as reported by labs).

Semi Permeable Membrane Devices (SPMD) were deployed at 29 sites for 30 day periods. These devices absorb PCBs from the water column to provide a long term integrated measure of PCB concentration. They are intended to be used as a screening tool to identify water bodies with higher (or lower) concentrations, are used in the Virginia 305(b) process, and can be the basis for 303(d) impairment listings. The SPMD data were not available to be used for the load estimates described in this draft report, but a comparison between SPMD data and these load estimates is planned and will be described in the final PCB load report.

Figures 2A-2D show the locations where samples were collected. Sample results are available from ICPRB, currently (January 2007) by request and eventually directly from the ICPRB website, www.potomacriver.org.

(3) The Chesapeake Bay Watershed Model

The POTPCB model requires daily input values for flow, PCBs, and carbon from the non-tidal Potomac River, tributaries in the lower Potomac watershed, point sources, and direct drainage areas. The U. S. Geological Survey (USGS) maintains stream gages at Little Falls, which is essentially the end of the non-tidal river, and at a few of the other tributaries entering the estuary. There are only scattered observations of PCBs and carbon in tributaries from which daily loads are needed. For the purpose of developing a tidal Potomac PCB TMDL, the Chesapeake Bay Watershed Model version 5 (WM5) was used to provide daily flows and generate daily estimates of carbon and PCBs loads from tributaries and direct drainage areas.

The advantages of using the WM5 are that the model is already built, has undergone extensive peer review, and has significant staff support from the Chesapeake Bay Program (CBP) to assist in interpretation of model results (US EPA, 2005; US EPA 2006a; US EPA 2006b). There are also certain constraints imposed by the WM5. These include the quality of the model calibrations and the characterization of the watershed. WM5 provides daily flow and constituent loads from tributaries and direct drainage watershed segments. All point and nonpoint source flow and loads in a tributary watershed are delivered to a stream reach with a direct link to a single Chesapeake Hydrodynamic Model (CH3D) cell. There are 17 tributaries defined by WM5 in the lower Potomac watershed, plus the Potomac River at Chain Bridge which is the input point for all of the Potomac basin above Washington, DC. The 17 tributary watersheds comprise 1,036 sq. mi. (about 44% ) of lower Potomac watershed area while the watershed above Chain Bridge is 11,560 sq. mi, or almost five times the size of the lower Potomac watershed. Flow and loads from direct drainage segments include only nonpoint sources and are proportionally allocated to adjacent CH3D model cells by drainage area. Point sources in the direct drainage segments are not included in the WM5 and their contribution to the tidal model is a separate input. The WM5 has 49 direct drainage segments that are further subdivided by county jurisdiction, which allows nonpoint source loads to be allocated by political subdivision. These segments account for 1,308 sq. miles (55%) of the lower Potomac watershed. An additional WM5 segment is defined for that portion of the District of Columbia served by combined sewers. In the WM5 framework, all runoff from this segment is assumed to reach the Potomac and Anacostia rivers via the combined sewer system, and is therefore counted as a CSO input (see below). Table 1 lists the tributaries and Figure 3 provides a spatial reference.

Using the WM5 model for organizing point and nonpoint loads for the Potomac PCB TMDL defines what areas are considered nonpoint source direct drainage to tidal waters versus upland tributaries. The effluent from all point sources located in direct drainage segments is considered to be delivered directly to the tidal model with no dilution or instream processes prior to delivery. Similarly, nonpoint source flow in direct drainage segments is delivered to the tidal model with no instream processes. The flow and constituent loads delivered to the tidal model from upland tributaries represents the combined contribution of point and nonpoint sources as well as instream processes in tributary stream reaches.

## III. Analyses of PCB Data

An examination of PCB data sets collected by multiple agencies between 1989 and 2003 (Tables 2-3) revealed a lack of consistency in the congeners analyzed, and some areas were more extensively sampled than others. To provide fair comparisons between data sets, a set of common congeners (i.e., reported in most or all studies) was identified and initial analysis of the historical data was restricted to those congeners. The Anacostia River and tidal fresh Potomac

River near Washington, D.C., were sampled more heavily than downstream regions, so the data were grouped by zones based on geographic region and salinity to avoid biasing the results.

(1) Pre and Post 1999 PCB Samples and Geographic Zones

As a quick test of trends over time (i.e., "are older data sets comparable to more recent data?"), the historical data were split into two pools, 1989-1999 and 2000-2003, and mean concentrations in the two pools compared. The analysis focused on total PCB concentrations in filets of bottom feeding fish (carp, catfish, eel) because total PCB concentrations in these species exceeded the guidelines for unrestricted human consumption in each jurisdiction, causing the affected water bodies to be listed as impaired. Fish tissue PCB concentrations were 53%-66% lower in the 2000-2003 period in all geographic zones monitored. Concentrations in bottom sediments were 64% and 20% lower in the Anacostia River and tidal fresh Potomac River, respectively. However, they were 949% higher in the oligohaline zone and 95% higher in the mesohaline zone of the Potomac (Figure 4). Based on this analysis, and considering the differences in the methods used to analyze the historical samples, the Steering Committee decided in March, 2006, that the most recent, least variable, and most accurate estimates of PCB concentrations from source areas presently in the estuary would be obtained by using data collected in or after 2000.

The evident decline in PCB concentrations with distance downstream that was revealed in the pre/post 1999 analysis of fish tissue and sediment samples prompted a similar analysis of whole water total PCB concentrations in tributaries to the tidal Potomac River. A longitudinal gradient was observed in tributary PCB concentrations from Washington DC to the mouth of the Potomac River estuary (Figure 5). As shown in Figure 6, tributary water column PCB concentration is correlated with the percent of area classified as urban in the watershed ($r^2 = 0.36$, $p<0.01$), but the relationship with simple distance from the Hickey Run in Washington, D.C., is stronger ($r^2 = 0.65$, $p<<0.001$). Concentrations were highest in District of Columbia tributaries of the tidal Anacostia River, and declined in tributaries near the District (i.e., Potomac River at Chain Bridge, Northeast and Northwest Branches of the Anacostia River, Virginia tributaries of the Potomac in the Washington metro area). PCB concentrations were low and fairly consistent in Potomac tributaries outside of a 40 kilometers radius from Hickey Run in the District, except for a few "hotspots." These findings are consistent with those by other investigators (Velinsky 2006).

Based on these results, the Steering Committee decided that the least variable and most accurate estimates of PCB concentrations entering the tidal Potomac River via tributaries and direct drainage would be obtained by grouping the data by river zones. Four watershed-based zones characterized by different PCB burdens and PCB-TSS relationships (see below) were established to estimate daily tributary and direct drainage loads within each zone for the POTPCB model. The zones are "DC Urban," "Near DC," "Chain Bridge," and "Else." Figure 7 shows the zone assignments by sub-watershed and tributary. These zone assignments can be updated when additional PCB and TSS data become available.

(2) Characteristics of Potomac PCB Sources and Choice of $PCB_{3\text{-}10}$ as Parameter to Model in POTPCB

The 10 homologs of PCBs, defined by the number of chlorine atoms attached to the biphenyl carbon rings, have different chemical properties and respond differently to environmental conditions. Model based predictions of fate and transport may be more accurate and efficient if a limited number of homologs is modeled and those results extrapolated to total PCBs. The choice of which PCB homolog(s) to model must be weighed against the distribution of PCB homologs in the river, and particularly the media that are listed as impaired. In the Potomac estuary, the dominant PCB homologs in the water column and in the tissue of bottom feeding fish are largely responsible for the 303d listing for total PCBs. Hypothetically, these homologs are the best choice for model parameter.

PCB TMDLs based on homolog-specific models have been developed for several locations in the United States, including the Delaware River estuary (DRBC 2003a, b). Pentachlorobiphenyls (penta-PCB) were selected as the model parameter for the Delaware PCB TMDL. Monitoring data at the time suggested penta-PCBs were the dominant homolog in fish tissue, and ambient data indicated that throughout the estuary this homolog represents approximately 25 percent of the total PCBs present (DRBC 2003a). The Delaware River Basin Commission and Limno-Tech, Inc. developed and calibrated a water quality model based on PCB homolog 5 and used it to extrapolate to total PCBs. This effort was the basis of the Delaware estuary's Stage 1 PCB TMDL (DRBC 2003b).

The mix of PCB homologs in the Potomac appears to be more complex than in the Delaware. Earlier work by area researchers indicates that significant variability occurs in the homolog distributions. Minor and major congener peaks are frequently found in homologs 1, 4, 5, 6, 7, and 8 (Baker 2006). PCB homolog distributions in different media in the 2000-2006 Potomac River estuary data were analyzed to identify the best homolog for the POTPCB model parameter. Mono- and dichlorobiphenyls (mono-PCB, di-PCB) were excluded from this analysis because one data set (George Mason University) did not include measurements for these two homologs. Percentages of the different homologs were thus calculated as a function of homologs 3-10 ($PCB_{3-10}$), not total PCB.

Potomac River monitoring data collected since 2000 indicate that PCB homologs 5-7 (i.e., penta-, hexa-, and hepta-PCBs) are the dominant homologs measured in filets of bottom feeding estuarine fish, with peak concentrations in homolog 6. Homologs 5-7 comprise about 77% of $PCB_{3-10}$ in the fish tissue, while lower weight (3-4) and higher weight (8-10) homologs make up approximately 17% and 6% of $PCB_{3-10}$, respectively (Figure 8).

The homolog distribution in bottom sediments, the habitat of the invertebrate food organisms of these fish, is somewhat different (Figure 9). Homologs 5-7 make up about 68% of $PCB_{3-10}$ and show a broad peak. Sources of bottom sediment are tributary runoff, including the sediment loads at Chain Bridge, and resuspension of existing bottom sediments. Homologs 4-7 are the dominant PCB forms in suspended particulates in the water column, with a tetra-PCB peak (Figure 10). They comprise about 84% of the $PCB_{3-10}$, with lower weight (3) and higher weight (8-10) homologs each making up 8% of $PCB_{3-10}$.

Homologs 3-4 are the dominant PCB forms dissolved in the estuarine water column, also with a tetra-PCB peak (Figure 11). They comprise about 65% of $PCB_{3-10}$, and higher weight (5-10) homologs are 35% of $PCB_{3-10}$. Comparison of the particulate and dissolved PCB homolog distributions in the water column suggest that heavier homologs have a higher affinity for particulates. Particulate matter includes suspended sediments, detrital organic matter, and living phytoplankton and zooplankton, all of which are filtered out of the water column by suspension feeding bottom invertebrates or eventually settle onto bottom sediments where they are consumed by deposit-feeding infauna. Thus, bottom invertebrates are feeding on particles dominated by homologs 4-7 or on sediments with a mixture of homologs. The dominance of homologs 5-7 in tissues of bottom-feeding fish suggests bottom invertebrates and/or the fish are preferentially accumulating the penta-, hexa-, and hepta-PCBs in their tissues.

Homolog distributions of PCBs in whole water (particulate + dissolved) are dominated by tetra-PCBs but have a broad representation of the other homologs (Figure 12). Whole water samples of PCBs in tributaries to the Potomac estuary also exhibit variability in their homolog distributions (Table 4). Homolog peaks in samples collected from below fall-line tributaries range from homolog 2 to 8, with the majority of peaks occurring in homolog 4 or 5. The peak homologs comprise from 22% to 51% of $PCB_{3-10}$. The largest source of freshwater to the estuary, the upper Potomac River, is dominated by homolog 2 at Chain Bridge near head-of-tide (median = 0.455, range = 0.26-0.8 ng/liter), followed by homolog 4 (median = 0.185, range = 0.07-0.66 ng/liter). Homolog 4 comprises about 27% of $PCB_{3-10}$. It should be noted that the six Chain Bridge samples were collected in the fairly narrow time frame of 8/23 -10/25, 2005, but represent flows ranging from the 4.2 percentile to the 77.8 percentile of the 2000-2005 Potomac River daily flow.

After considering the varied distributions of PCB homologs in bottom feeding fish, their habitats, and the tributary sources of PCBs to the Potomac estuary, the Steering Committee decided in a conference call on December 1, 2006 to develop the TMDL model specific to homologs 3-10 rather than just one or two homologs. $PCB_{3-10}$ is more inclusive of all contaminant sources, and the broader congener distribution provides a larger target for the TMDL. Modeling $PCB_{3-10}$ will eventually facilitate reduction strategies among the various source categories, and will minimize concerns about homolog variability at different sites. Finally, it minimizes any potential disconnect between PCB sources and observed ambient data. Mono- and di- homologs were excluded primarily because a significant data set (George Mason University) on which the tributary load calculations are based in part does not include these homologs.

(3) Estimating PCB Concentration from Total Suspended Solids

Estimates of daily PCB loads from each Potomac estuary tributary and direct drainage watershed are needed in the POTPCB Model. Loads are estimated on a daily time step to be consistent with USGS stream flow data, which tends to be available on a daily time step. Daily PCB loads are not available in any watershed, so analyses were done to find relationships between PCB concentration and another parameter for which daily values are available from the WM5. PCBs tend to bind to organic particles in suspended sediments. Hence, they are often associated with total organic carbon (TOC), particulate organic carbon (PC), or total suspended solids (TSS), all of which are modeled parameters in the WM5. Samples collected at tributary stations near head-of-tide and at Chain Bridge (Potomac River fall-line) were used to derive regressions between total PCB and these water quality parameters. After considering data availability and the WM5 performance in modeling each of the water quality parameters, a set of monitoring-based regressions was selected and applied to WM5 output data to calculate the needed daily PCB loads from the watershed.

For this analysis, samples collected during both base and wet flow conditions between April 2002 and February 2005, and analyzed for PCBs by George Mason University (GMU), Chesapeake Biological Laboratory (CBL), the Academy of Natural Sciences (ANS), and the Geochemical and Environmental Research Group of Texas A&M University (GERG), were used to explore relationships between total PCB and four water quality parameters: PC, dissolved organic carbon (DOC), TOC, and TSS. Relationships between particulate and dissolved PCB fractions and the water quality parameters were also explored where possible. In Fall 2006 when this analysis was done, a total of 81 paired PCB and water quality samples were available for Maryland tributaries to the tidal Anacostia River, 24 for District of Columbia tributaries to the Anacostia River (Hickey Run, Lower Beaverdam Creek, Watts Branch), 12 for multiple Virginia tributaries to the Potomac River, and 6 for the Potomac River at Chain Bridge. The data were grouped and analyzed by laboratory and location in order to minimize possible sources of variance. Total and particulate PCB correlated significantly ($p<0.05$) and strongly ($r^2$ 0.24-0.86) with TSS, TOC, and PC, but did not correlate with DOC. Dissolved PCB did not correlate strongly with any of the water quality parameters (Table 5). These results confirm the affinity of PCBs for suspended solids, and particularly organic particles. The analysis results also indicate that the relationships vary by location. Samples from the District of Columbia had the highest, steepest regression slopes, while samples from most Virginia tributaries located more than 20 km from the District had the lowest, shallowest regression slopes (Giles Run was an exception).

The possibility of using flow instead of TSS or carbon to estimate watershed PCB loads was also explored. PCB concentration correlates with flow because TSS concentration correlates with flow. Flow-based and TSS-based estimates of PCB concentrations were compared with observed PCB concentrations. Flow is monitored near PCB sample locations at gaging stations located on the Northeast and Northwest branches of the Anacostia River, Watts Branch, and the Potomac River at Chain Bridge. USGS daily flow data for these gages were downloaded (http://waterdata.usgs.gov/md/nwis/current/?type=flow) and matched to the corresponding PCB samples. TSS-based estimates of PCB concentrations outperformed flow-based estimates in comparisons with observed PCB concentrations for the Northeast and Northwest Anacostia branches and Watts Branch (Figure 13). In another analysis, multiple linear regressions of the Anacostia data show that TSS (mg/liter) is a better predictor of total PCB (ng/liter) than flow (cfs), and the predictive ability of flow is not significant ($p<0.05$) after adjusting for TSS (Table 6).

TSS was preferred over carbon as a predictor of PCB because there are more PCB-TSS data pairs (123 in four geographic zones) than PCB-carbon data pairs (31 particulate carbon or 36 total organic carbon in two zones) from which to build regressions, and the TSS simulation in the WM5 is currently better calibrated than the organic carbon simulation (US EPA, 2006c).

Total PCB concentrations (ng/liter) were derived as follows from average daily TSS concentrations (mg/liter), which were calculated from WM5 flow and TSS load output data:

| Zone | Regression equation |
|---|---|
| DC Urban | [total PCB] = 1.0264 $[TSS]^{0.9207}$ |
| Near DC | [total PCB] = 0.2639 $[TSS]^{0.5876}$ |
| Chain Bridge | [total PCB] = 0.3703 $[TSS]^{0.4149}$ |
| Else | [total PCB] = 0.0446 $[TSS]^{0.4266}$ |

The DC Urban regression is applied to TSS concentrations in two direct drainage watershed segments in and near Washington, DC: PL2_4810_0000, which borders the tidal Anacostia River, and PL7_4940_0000, which borders the Washington Shipping Channel and the Potomac River between Rock Creek and the Anacostia River. The CSO segment in Washington, DC also was assigned to the DC Urban zone. The Chain Bridge regression is applied solely to TSS loads entering CH3D cell 2106, the most upstream cell of the hydrodynamic model spatial grid, and represents all inputs from above the fall-line. The Near DC regression is currently applied to TSS concentrations in 11 direct drainage watershed segments and tributaries, most of which are within 20 km of Washington, DC: PL0_4510_0001, PL1_4540_0001, PL1_4780_0001, PL7_4910_0000, PL7_4960_0000, PL0_4961_0000, PL7_4980_0000, PL0_5000_0001, PL0_5090_0000, PL1_5130_0001, PL0_5251_0000. The Else regression is applied to TSS concentrations in all other direct drainage watershed segments and tributaries. A map of the boundaries of each zone is shown in Figure 7. Regressions for the four zones show distinctly different regression slopes.

After the decision was made to model PCB homologs 3-10, the TSS:PCB regressions were recalculated with these results:

| Zone | Regression equation | Correlation coefficient ($r^2$) |
|---|---|---|
| DC Urban | $[PCB_{3-10}] = 0.9967\ [TSS]^{0.9426}$ | 0.59 (n = 33) |
| Near DC | $[PCB_{3-10}] = 0.3290\ [TSS]^{0.5059}$ | 0.63 (n = 94) |
| Chain Bridge | $[PCB_{3-10}] = 0.1131\ [TSS]^{0.5970}$ | 0.86 (n = 6) |
| Else | $[PCB_{3-10}] = 0.0456\ [TSS]^{0.5026}$ | 0.52 (n = 25) |

These regressions included the previous suite of data sets as well as 2005-2006 samples analyzed by Battelle Laboratories. The $PCB_{3-10}$-TSS regression lines with their underlying data are shown in Figure 14. The change from total PCB to $PCB_{3-10}$ did not greatly affect the regressions in three of the four zones, but the Chain Bridge regression slope dropped noticeably when the mono- and di- homologs were excluded (see Figure 15).

While the PCB model will be run with PCB3-10 input loads, water quality standards are based on total PCB concentrations and so the PCB3-10 loads for sources will need to be translated back to total PCBs for the TMDL. As indicated in the discussion above, the ratio of PCB3-10 to total PCB varies by source category. The method by which this translation will be done is likely to take into account those source category differences, but exact approach to be used is still under discussion by the Steering Committee.

## IV. Calculation of External Loads by Source Category

(1) Calculation of Tributary and Direct Drainage Loads

Output from Chesapeake Bay Watershed Model, Phase 5, was used to estimate daily flows and loads of suspended solids, carbon, and PCB delivered from the Potomac River watershed to each DynHyd cell (hydrodynamic component of POTPCB model) in the POTPCB estuary model. The WM5 model simulates watershed hydrology and nutrient cycles associated with different land uses, and generates flow, nutrient, and sediment loads to the model cells of the 3-dimensional Chesapeake Hydrodynamic Model (CH3D). The spatial grid of POTPCB model DynHyd cells generally matches that of the CH3D model cells except in Washington, DC and some tributaries where additional or smaller DynHyd cells were created to provide higher spatial resolution.

Table 7 shows how flows and loads from WM5 tributaries are delivered to DynHyd cells. In most cases, each tributary empties into a single CH3D and DynHyd model cell, but there are several cases where more than one tributary is connected to a single CH3D cell. In those cases, the total tributary flow and load is apportioned to DynHyd cells as indicated by the DH Fraction.

In WM5 output, flow and load from the 49 direct drainage watershed model segments is identified only by the CH3D model cell the flow and load go to and not by the watershed model segment that it comes from. In most cases there is a 1:1 relationship between DynHyd cells and CH3D cells, but in the Anacostia River and some other embayments there are several DynHyd cells to each CH3D cell. Direct drainage flow and load to CH3D cells is apportioned to DynHyd cells by the fractions indicated in Table 8. The fractions were determined by visual comparison of CH3D and DynHyd cell boundaries and watershed model segment boundaries.

The tributary and direct drainage loads produced by the WM5 model for each CH3D cell were imported into MS Access 2003, processed separately, then joined and summed to obtain total watershed load to each DynHyd cell of the POTPCB model. In both the tributary and direct drainage data sets, the modeled daily sand, silt, clay, and algae dry weight loads to each CH3D cell were summed to obtain a TSS load, which was divided by the modeled flow to obtain a TSS concentration. The TSS-$PCB_{3\text{-}10}$ regression (PCB code) assigned to each CH3D cell was applied to calculate a $PCB_{3\text{-}10}$ concentration in ng/liter. This concentration was multiplied by flow to obtain a $PCB_{3\text{-}10}$ load to the CH3D cell in g/day. In a last step, the modeled carbon and sediment daily loads and calculated $PCB_{3\text{-}10}$ daily load to the CH3D cells were apportioned to DynHyd model cells according to the fractions in Tables 7 and 8. Tributary and direct drainage loads to DynHyd cell were then joined and summed to create a total daily watershed loads to each DynHyd cell. The field names in the final load file are listed in Table 9.

WM5 output for an eleven year period from 1994 through 2004 was processed as described above and annual loads of $PCB_{3\text{-}10}$ were calculated to get a sense of the relative magnitude of PCB loads from tributaries and direct drainage areas with results, shown below, grouped into the Potomac river at Chain Bridge, the sum of all other tributaries, and the sum of all Direct Drainage areas.

Annual total $PCB_{3\text{-}10}$ loads, grams/year

| | Avg | Min | Max |
|---|---|---|---|
| Potomac R. @ Chain Br. | 11,156 | 3,183 | 30,682 |
| ∑Other Tribs | 1,876 | 837 | 3,790 |
| ∑All Dir. Drain area | 4,467 | 3,099 | 9,441 |

The Potomac River at Chain Bridge is the dominant input of PCBs to the Potomac estuary. From these results it is apparent also that annual load is highly dependent on annual flow. Nearly all (99%) of the Other Tributary load is nonpoint source in origin (point source loads are described below). It is interesting to note the Direct Drainage, comprising 55% of Lower Potomac watershed area, contributes 70% of nonpoint source load (calculated as sum of Dir Drain and ∑Other Tribs). This may reflect the relative proportions of the higher PCB loading rate zones in Direct Drainage and Tributaries segments or, recalling that PCB loads are predicted based on regressions with TSS, it may reflect higher TSS loads per unit area generated by the Chesapeake Bay Watershed Model in direct drainage areas versus tributaries. See Figure 16 for an illustration of average annual PCB3-10 loads from tributaries here.

The Potomac PCB model simulates sorption dynamics of PCBs to organic carbon in the water column, net solids burial to the sediment layer, and exchange with the atmosphere. Thus fate and transport of PCBs in the model is directly linked to organic carbon and carbon load inputs to the model must be estimated as well as PCB inputs.

In the watershed model, carbon is represented in three forms: refractory organic carbon (refc), labile, organic, non-algal carbon (bodc), and biotic carbon (algc). Bodc is carried in the watershed model in units of oxygen that can ultimately be taken up by biological oxygen demand, or BOD, so it is analogous to BOD-ultimate (US EPA 2006c). Refc is considered to be equivalent to particulate detrital carbon (PDC). Average annual refc (PDC) carbon load predicted by the WM5 for all tributaries and Direct Drain area is 31 million kg. Of that amount, 17.4 million kg is delivered by the Potomac River at Chain Bridge. By comparison, the sum of refc for all wastewater treatment plants is 1 million kg/year. Average annual carbon loads for each tributary, total and as a kg/acre yield, are shown in Table 10.

(2) Calculation of Wastewater Treatment Plant Loads

There are more than 60 permitted municipal and industrial wastewater treatment plants (WWTP) in the Potomac watershed downstream from Chain Bridge. PCB loads were calculated for the 22 WWTPs with the largest annual flow, accounting for approximately 95% of the total WWTP flow in the watershed. Prior to this study no PCB samples had been analyzed using methods with detection limits below the states' water quality standards. For this study one or more samples were collected at 16 facilities and analyzed using Method 1668A (EPA 1999), which provided congener specific detection limits in the range of 2-8 pg/l. Individual samples were used only after passing a review of established decision rules (VA DEQ, 2006). Not enough samples were collected to make any judgement about PCB concentrations varying with season or during wet versus dry flow conditions. Therefore, each facility was assigned a constant $PCB_{3-10}$ concentration based on the mean of all samples collected at that facility or, if no samples were collected, then the mean of all samples in that state was used. (The Maryland mean $PCB_{3-10}$ was calculated excluding NSWC-Indian Head because that facility was deemed not representative). Daily $PCB_{3-10}$ loads are calculated by multiplying the facility concentration by the monthly average or daily (for Blue Plains) flow. Flows were obtained from the Chesapeake Bay Program Point Source Tracking database (Blue Plains flows obtained from DC WASA).

Three facilities, Beltsville USDA East, Beltsville USDA West, and UOSA, are located within

WM5 tributary watersheds. As such the PCB load from these facilities is not explicitly added to the external load calculation for the PCB model, rather their load is implicit in the relevant tributary load calculation. These facilities are included in this summary for tracking purposes only. The other nineteen facilities are located in direct drainage watershed segments and their effluent load is assumed to be delivered directly to tidal waters, i.e. a PCB model segment. Table 11 lists the 22 WWTP being tracked for the POTPCB model and Figure 17 provides a spatial reference. For calendar year 2004, it is estimated that these facilities delivered 800 grams $PCB_{3-10}$ to the tidal Potomac. Of that amount, the Blue Plains WWTP accounted for 724 grams (90%).

Carbon in WWTP effluent typically is measured as BOD. Average annual BOD5 was estimated from DMR data or from the Chesapeake Bay Program Point Source tracking database. This average annual BOD5 was converted to a carbon concentration using these conversions:

$BOD_5 * 2.84 = BOD_{ult}$
$BOD_{ult} * .2475 = \text{Carbon}$
Thus, $BOD_5 * 0.7 = \text{Carbon}$

All of this WWTP carbon is assumed to be particulate detrital carbon (PDC). Table 12 shows the BOD and PDC concentrations assigned to each WWTP facility.

(3) Calculation of PCB Loads from Contaminated Sites

Sites where PCBs have been used or stored are a potential source of PCB contamination to the Potomac River. Staff at the District of Columbia Department of the Environment (DC DOE), Maryland Department of the Environment (MDE), and Virginia Department of Environmental Quality (VA DEQ) reviewed their records to identify sites of known PCB releases or soil contamination. Samples previously collected provided estimates of PCB concentration in soils at these sites, some of which have already been through a remediation process. Annual soil loss at each site was estimated using the Revised Universal Soil Loss Equation, Version 2 (RUSLE2) methodology (manuals, program, and databases available at http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm).

Of the twenty one sites identified as possible sources of PCBs, thirteen sites are located in WM5 direct drainage watersheds and eight sites are located within tributary watersheds. Annual PCB loads were estimated for the tributary watershed sites but the loads are not explicitly input to the POTPCB model as they are implicit in the load estimated for the tributary (see section IV(1) above). PCB loads for sites in direct drainage watersheds are input to the POTPCB model as a constant daily load (annual load/365). Table 13 lists the sites and annual PCB load estimates and Figure 18 provides a spatial reference. The thirteen sites that are inputs to the POTPCB model collectively contribute 22.85 grams/year total PCB. The eight additional sites in tributary watersheds are estimated to contribute 6.80 grams/year total PCB.

State agencies have considered other potential contaminated sites, such as spill events at power distribution substations. However, the PCB loading computations for these sources using the RUSLE2 methodology yielded insignificant PCB loadings for inclusion in the model. Additional contaminated sites may be added to the model if more information becomes available that suggests a significant source. Calculation of PCB loads from these sites was based on total PCBs rather than $PCB_{3-10}$, so the current these loads may be considered a "conservative" estimate.

(4) Atmospheric Deposition

No recent Potomac watershed studies of atmospheric deposition of PCBs to surface waters of the estuary are available. (Atmospheric deposition to land surfaces is computed as nonpoint source runoff either through tributary loadings or direct drainage nonpoint source runoff.) Literature review suggests net deposition rates are higher near urban centers compared to rural areas. The Chesapeake Bay Program Atmospheric Deposition Study (CBP, 1999) estimated a net deposition of 16.3 ug/m$^2$/year total PCB for urban areas and a net deposition of 1.6 ug/m$^2$/yr total PCB for regional (non urban) areas. In the Delaware estuary, an extensive atmospheric deposition monitoring program found PCB deposition rates ranging from 1.3 (non urban) to 17.5 (urban) ug/m$^2$/year total PCB (DRBC, 2006). The District of Columbia's Anacostia PCB TMDL study (Environmental Health Administration, 2003), using the CBP Atmospheric Deposition Study as a reference, used 16.3 ug/m$^2$/year as the net atmospheric deposition rate in that urbanized watershed.

For at least initial POTPCB model runs, it was decided to use deposition rates from the CBP 1999 report. Concentrations of only 61 of the 209 congeners were reported in the study, thus homolog distributions in rainwater and air and $PCB_{3-10}$ concentrations could not be calculated. Daily inputs provided to the POTPCB model were for total PCB. The Potomac estuary was divided into 3 zones: Urban, Regional, and Transition. POTPCB model segments in the Urban zone receive an atmospheric deposition of 16.3 ug/m$^2$/year in equal daily amounts while model segments in the Regional zone receive an atmospheric deposition of 1.6 ug/m$^2$/year in equal daily amounts. Deposition rates in the Transition zone were linearly interpolated between the Urban and Regional rates. With the Urban boundary at Hunting Creek and Regional boundary at Chopawamsic Creek, the preliminary estimate of net annual atmospheric deposition to Potomac estuary is 3,130 g/yr total PCB. Figure 19 shows the locations of the three zones.

(5) Combined Sewer Overflows

Two areas, approximately 1/3 of the District of Columbia and a smaller area in Alexandria, VA, are served by combined storm and sanitary sewers (Figure 20). During high precipitation events, when storm water exceeds wastewater treatment plant capacity, the excess flow is diverted to nearby streams (the Anacostia R., Rock Creek, Potomac R., and Four Mile Run). There are 53 combined sewer outfalls in the District of Columbia and 4 outfalls in Alexandria. These combined sewer overflows, or CSO, are treated as point source inputs to the POTPCB model. Three parameters need to be estimated: flow, PCB concentration, and carbon.

Daily flows for each CSO outfall were obtained from a CSO model developed by LimnoTech, Inc for the District of Columbia and Alexandria (LTI, 2006) for the period April 2003 to April 2005. For other periods, the monthly total CSO flow reported in the Chesapeake Bay Program point source tracking database was used with the monthly flows divided into equal daily increments and total flow apportioned among the CSO outfalls in the same proportion as represented in the LimnoTech model for 2003-2005.

PCB concentration was estimated using the DC Urban TSS:PCB regression. The event mean concentration TSS from samples collected for the District of Columbia Long Term Control Plan study (Greeley and Hansen July 2002) was 156 mg/l. For Alexandria, the median TSS concentration of 65 samples collected in 2002-2003 was 53 mg/l. Inserting these values into the regression equation

$$[PCB_{3\text{-}10}] = 0.9967\ [TSS]^{0.9426}$$

yields a $PCB_{3\text{-}10}$ concentration of 116 ng/l for DC CSO and 42 ng/l for Alexandria CSO. These concentrations were applied uniformly to all CSO flows to compute PCB loads to the POTPCB model. From 1994 through 2004 the average annual load of $PCB_{3\text{-}10}$ was estimated to be 1,124 g/year from DC CSO and 24 g/year from Alexandria CSO.

Two samples were collected from DC CSOs in the summer of 2006 and analyzed for PCB and TSS. A comparison of observed and predicted $PCB_{3\text{-}10}$ concentration is shown below:

| Sample | TSS, mg/l Observed | $[PCB_{3\text{-}10}]$, ng/l Observed | $[PCB_{3\text{-}10}]$, ng/l Predicted |
|---|---|---|---|
| O St. | 29.8 | 23.9 | 24.4 |
| Main St. | 107 | 64.1 | 81.6 |

Only particulate detrital carbon (PDC) and biotic carbon (BIC) loads need to be computed for input to the POTPCB model. Long Term Control Plan monitoring in 2003-2004 provided measurements of total organic carbon (TOC) and dissolved organic carbon (DOC).

$$TOC = BIC + PDC + DOC$$

Assuming that BIC is 0 in CSO flow, this equation can be written as:

$$PDC = TOC - DOC$$

The TOC event mean concentration in Long Term Control Plan monitoring was 18.2 mg/l and the DOC event mean concentration was 14 mg/l dissolved organic carbon (DOC). Thus, PDC = 4.2 mg/l. This concentration was applied to all CSO flows in both DC and Alexandria. Average annual PDC load from CSOs is estimated to be 48,000 kg/year

## V. Summary of External Loads to the Potomac PCB model

For all of these source categories, there remain questions and uncertainties regarding load estimates and evaluation of data and estimation procedures is continuing. Once a calibrated PCB model is available it will be possible to identify which sources, in which places, are most critical for meeting water quality standards, and that information will set priorities for additional work to refine these estimating procedures. Based on the procedures described in this report, it is estimated that about 22.3 kg $PCB_{3\text{-}10}$ are delivered to the tidal Potomac in an average year. About 42% of that amount comes from the Potomac River at Chain Bridge and all nonpoint sources (the Potomac River, other tributaries, direct drainage, atmospheric deposition) combined account for 91% of the total load. Delivery of nonpoint source PCBs appears to be highly dependent on annual precipitation and runoff. The total load may be more than 40 kg in a wet year and less than 10 kg in a dry year. See Table 15 for a comparison of PCB loads from source categories.

Although these estimates indicate that nonpoint sources are by far the major source of PCBs for the entire Potomac estuary, there are particular localities for which a significant fraction the total external PCB load to a single PCB model cell comes from other source categories (WWTP, CSO, contaminated sites).

A review of total loads to each PCB model cell shows that the cells with the highest annual PCB loads per model cell volume tend to be in the upper estuary, in the District of Columbia and certain embayments in Maryland and Virginia. This should not be surprising since historical data show a strong gradient in PCB concentration away from DC and the load estimating methods used here are based on that data. Finding load reductions to meet water quality standards will be especially challenging because the District of Columbia has the lowest PCB standard while having the highest nonpoint source loading rates.

Average annual particulate detrital carbon (PDC) loads are estimated to be 31 million kg. The Potomac River at Chain Bridge accounts of 57%, all other tributaries plus direct drainage account for 40%, and WWTPs account for 3%. The carbon parameter in the WM5, however, is not well calibrated and so new carbon estimation procedures have been developed and (as of January 27) evaluated.

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# APPENDIX A: FIGURES

Figure 1. Location of PCB impaired waters in the tidal Potomac. This map is a general reference only. The jurisdictions' 303(d) lists should be consulted for exact descriptions of the extent of impairments. Non tidal waters listed as impaired by PCBs are not addressed by this TMDL and are not shown on this map.

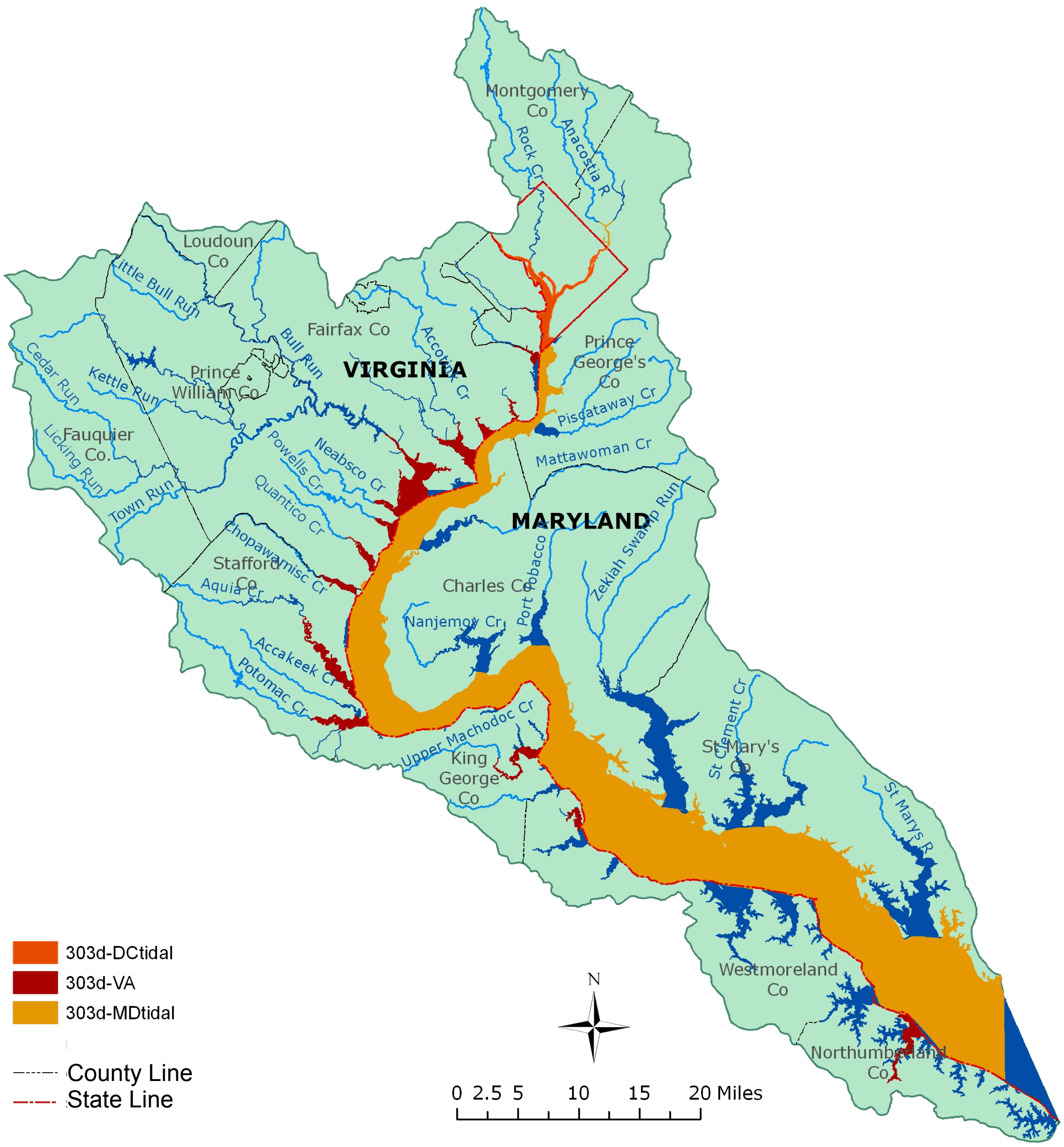


Figure 2-A. PCB Sampling Locations for water column samples collected in 2005-2006. Specific locations and sample analysis results are available from ICPRB.

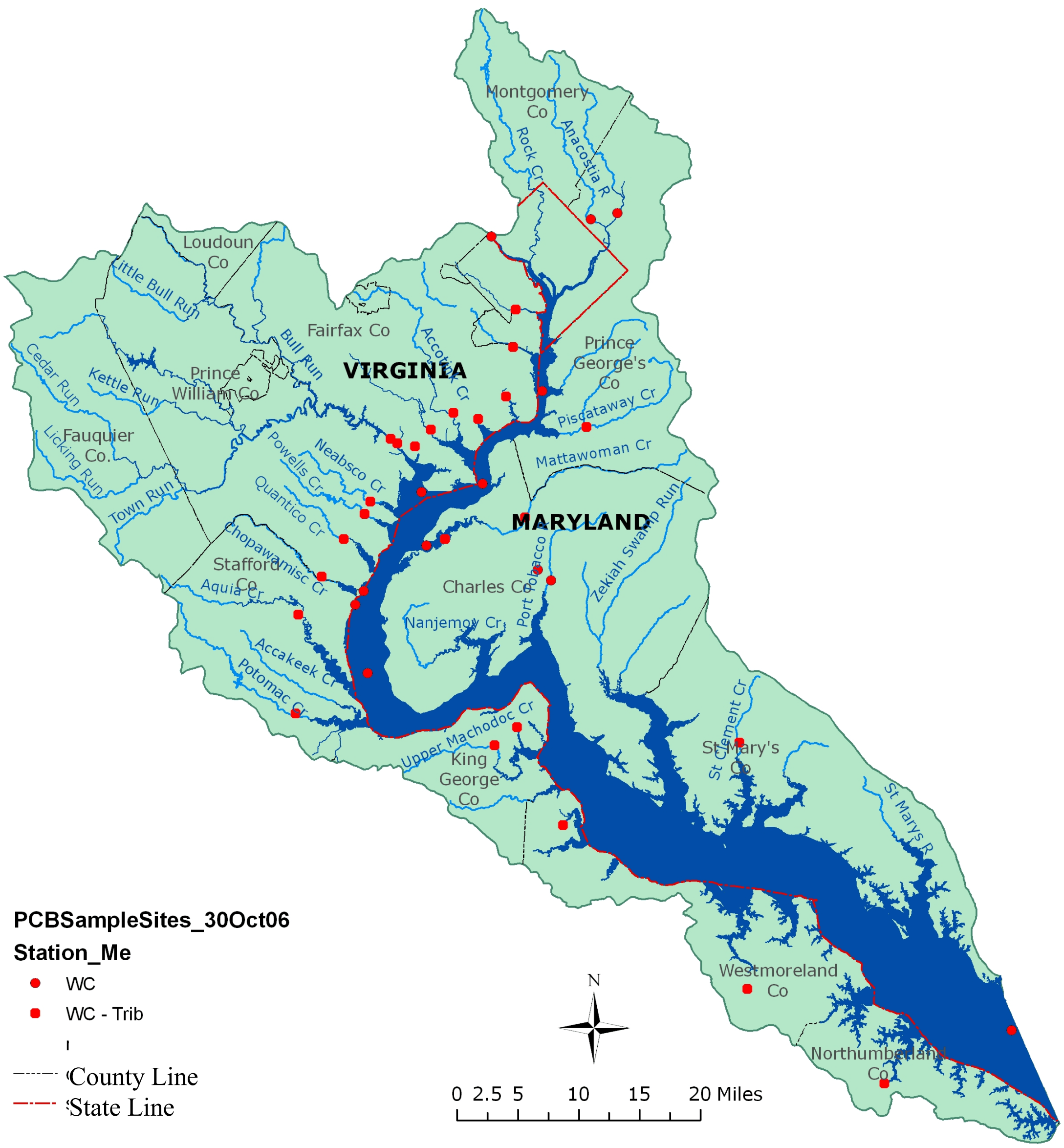


Figure 2-B. PCB Sampling Locations for bed sediment samples collected in 2005-2006. Specific locations and sample analysis results are available from ICPRB

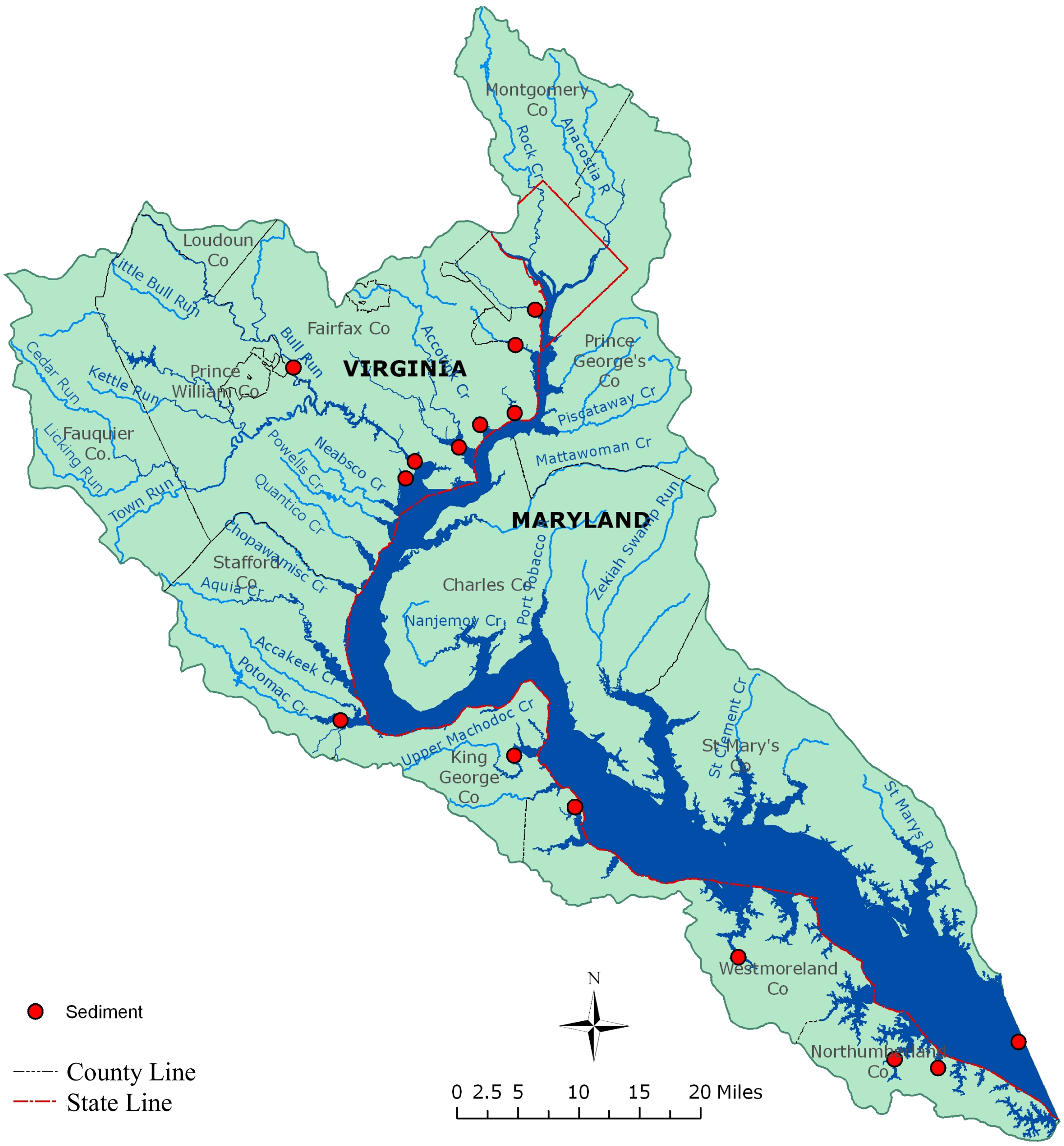


Figure 2-C. PCB Sampling Locations for waste water treatment facilities collected in 2006. Some of these samples were collected by cooperating facilities and the results made available to the states for this project. Specific locations and sample analysis results are available from ICPRB.

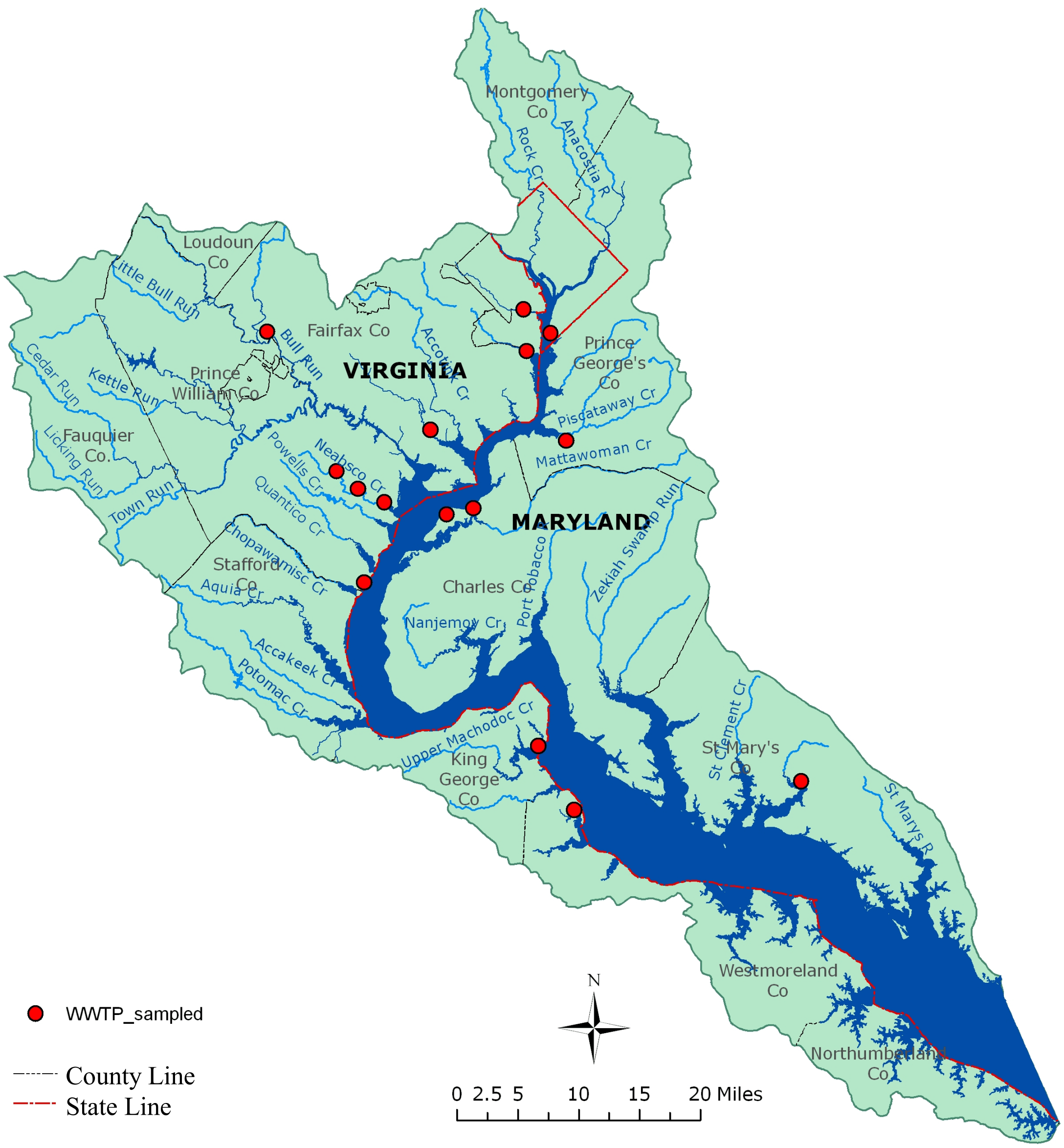


Figure 2-D. PCB Sampling Locations for Semi Permeable Membrane Devices (SPMDs) collected in 2006. Specific locations and sample analysis results are available from ICPRB

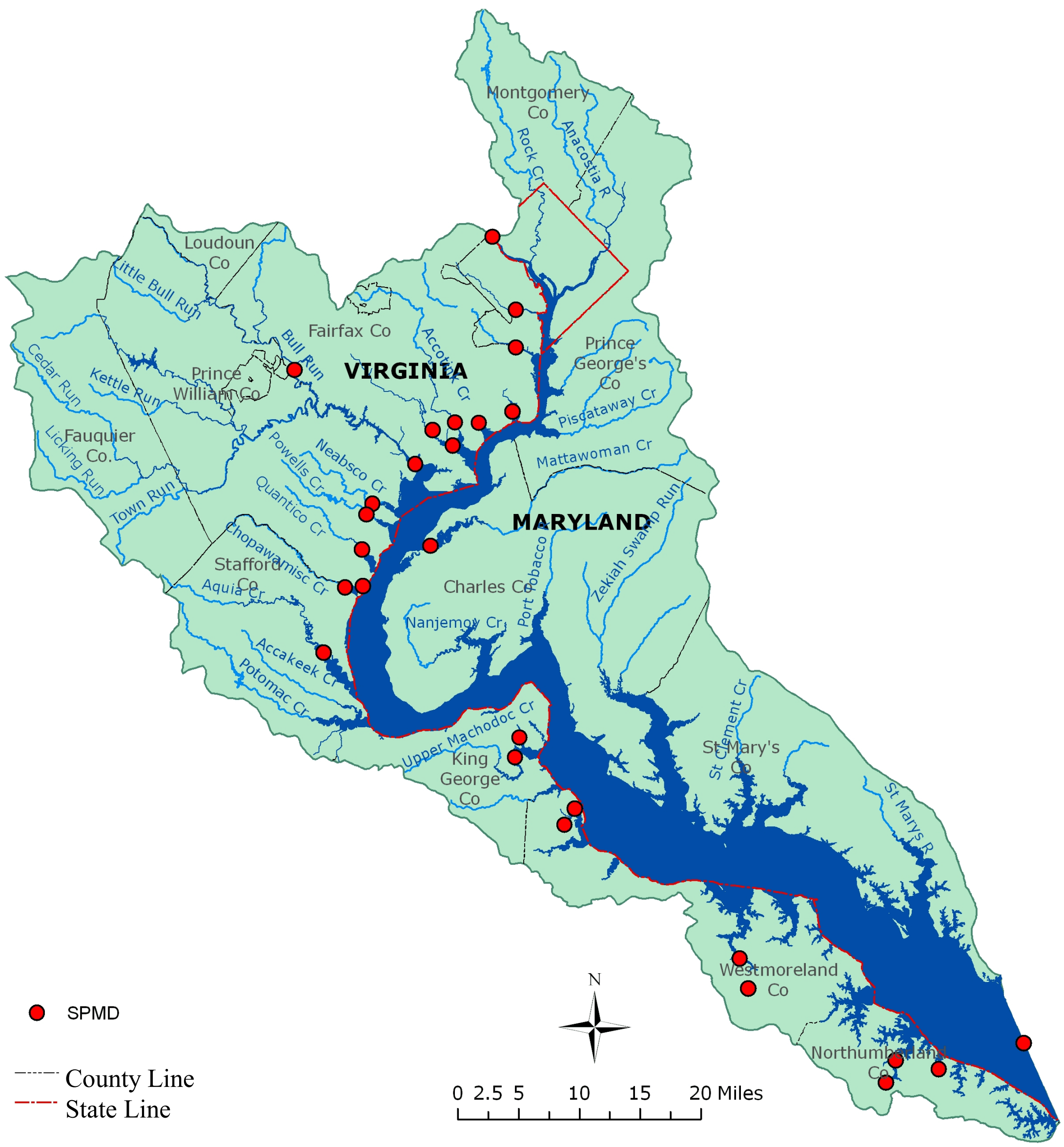


Figure 3. Tributary, direct drainage, and combined sewer overflow (CSO) watershed segments contributing to the Potomac River estuary in the Chesapeake Bay Watershed Model, Phase 5.

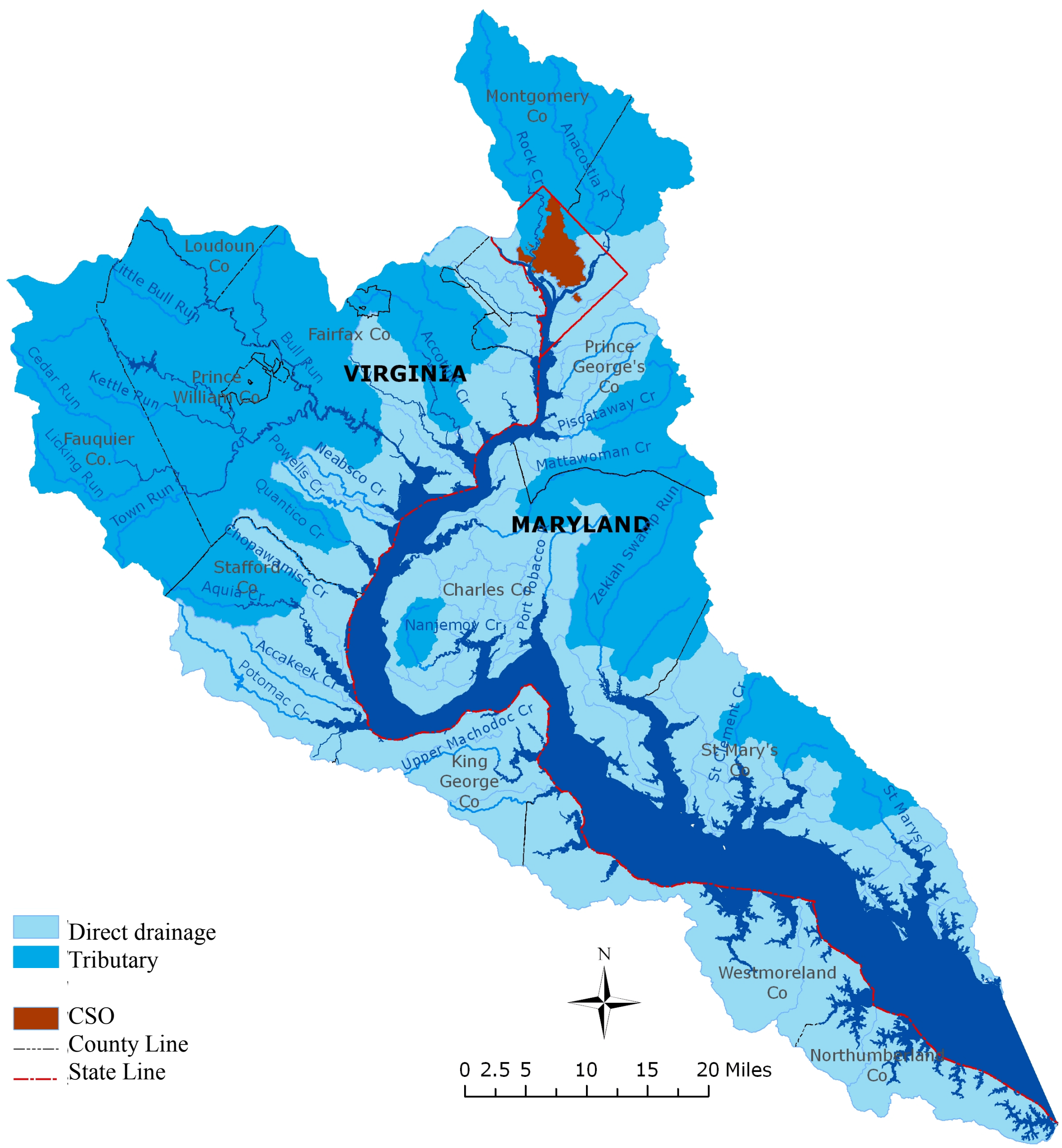


Figure 4. Observed total PCB concentrations in estuarine sediments and fish. Filets of bottom feeding fish (carp, catfish, eel), by river zone, before and after 2000. Statistics: minimum, average (value shown), and maximum. Values have been rounded to the nearest whole number. River zone: AR, Anacostia River; TF, tidal fresh Potomac River; OH, oligohaline Potomac River; MH, mesohaline Potomac River.

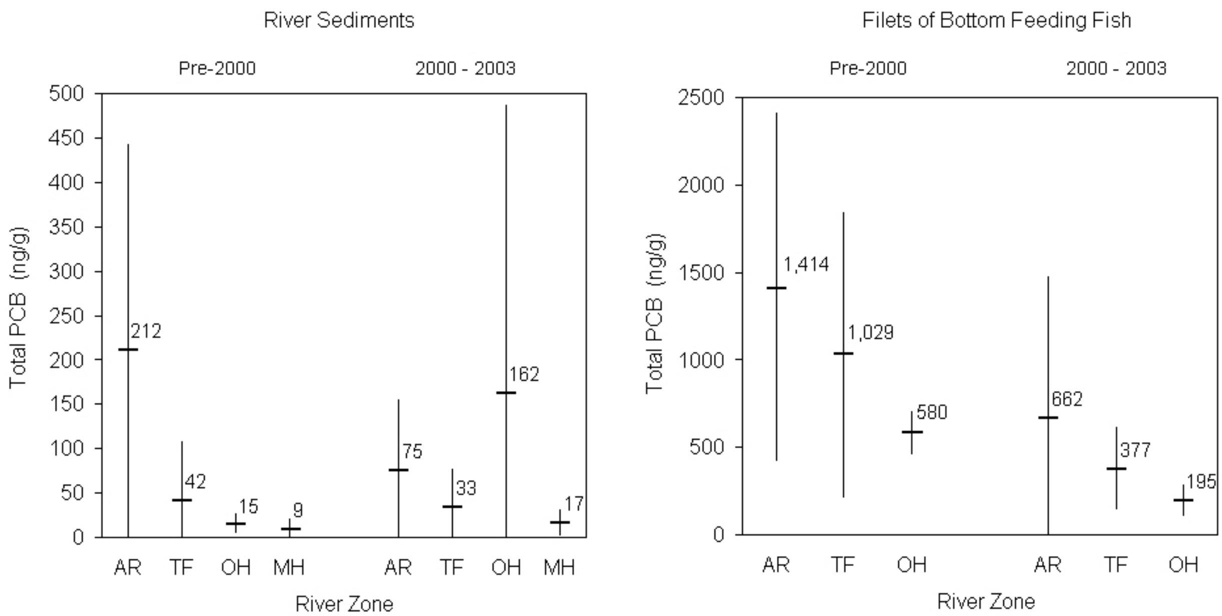


Figure 5. Change in total PCB (ng/liter) median concentration with distance from Hickey Run in Washington, DC. The log-log regression has an r2 = 0.65 (p<<0.001).

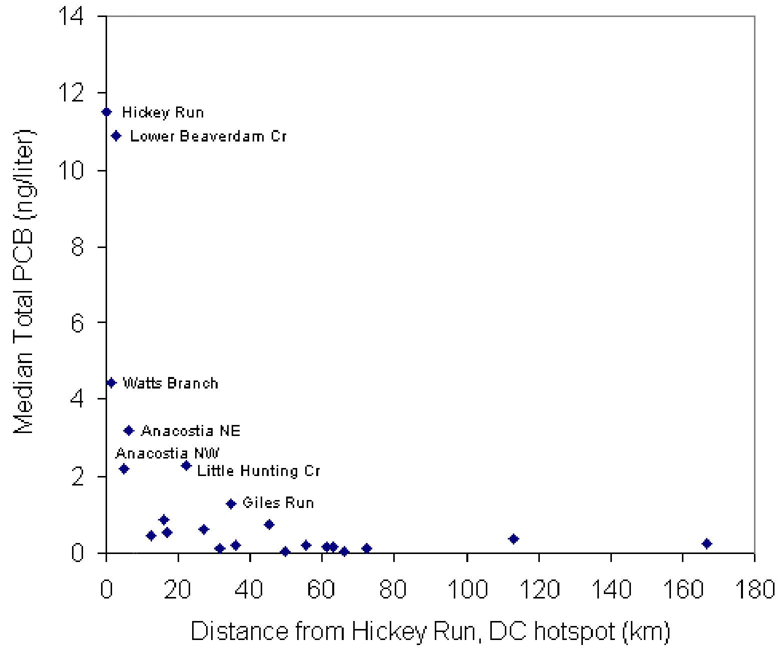



Figure 6. Median Total PCB in tributary water column samples (ng/l) versus %urban land area in watershed. The log-log regression has an $r^2 = 0.36$ ($p<0.01$).

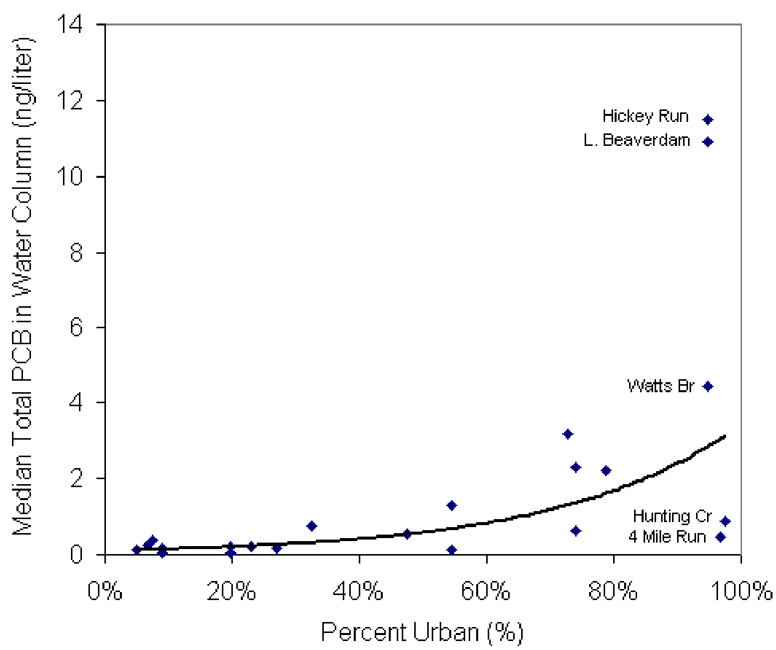


Figure 7. Zone assignments by WM5 segment, as of November 2006. Black circles indicate sample locations for data used in regressions that determined PCB:TSS zones.

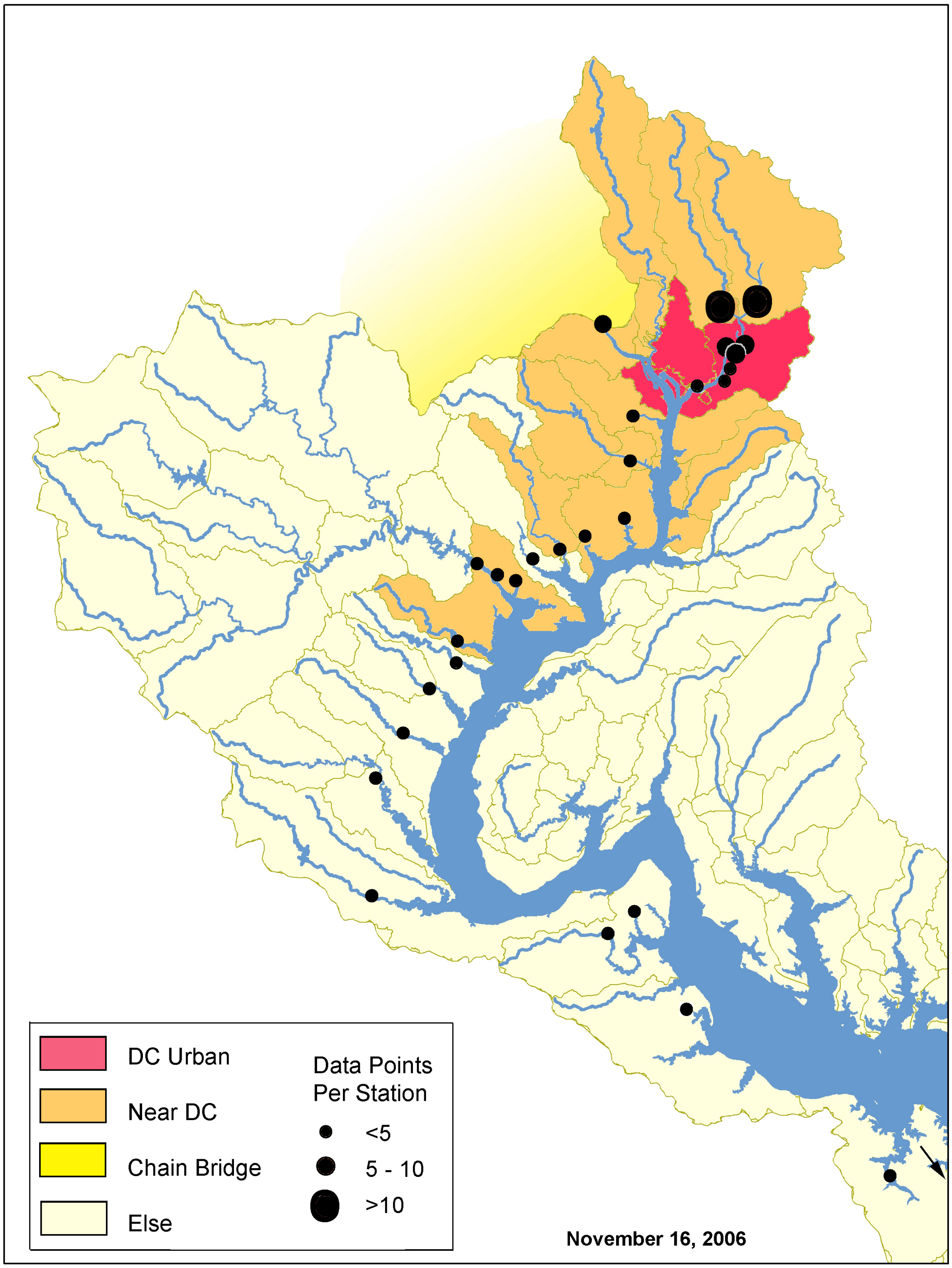


Figure 8. Distribution of PCB homologs in filets of bottom feeding fish, as percent of $PCB_{3\text{-}10}$. Bars and whiskers indicate 5th%, 25th%, 75th%, and 95th% and solid circle indicates 50th% of 53 samples collected 2000-2003 and analyzed for the Maryland Department of the Environment Fish Tissue Monitoring Program, Virginia Department of Environmental Quality Routine Tributary Sampling, and Fish and Wildlife Service District of Columbia monitoring project. Percentages are calculated from homolog totals as reported by the laboratories. No attempt was made to correct for congener level contaminants as indicated by sample blanks. Collection sites range from the tidal fresh Potomac and the upper Anacostia River to Maryland Point.

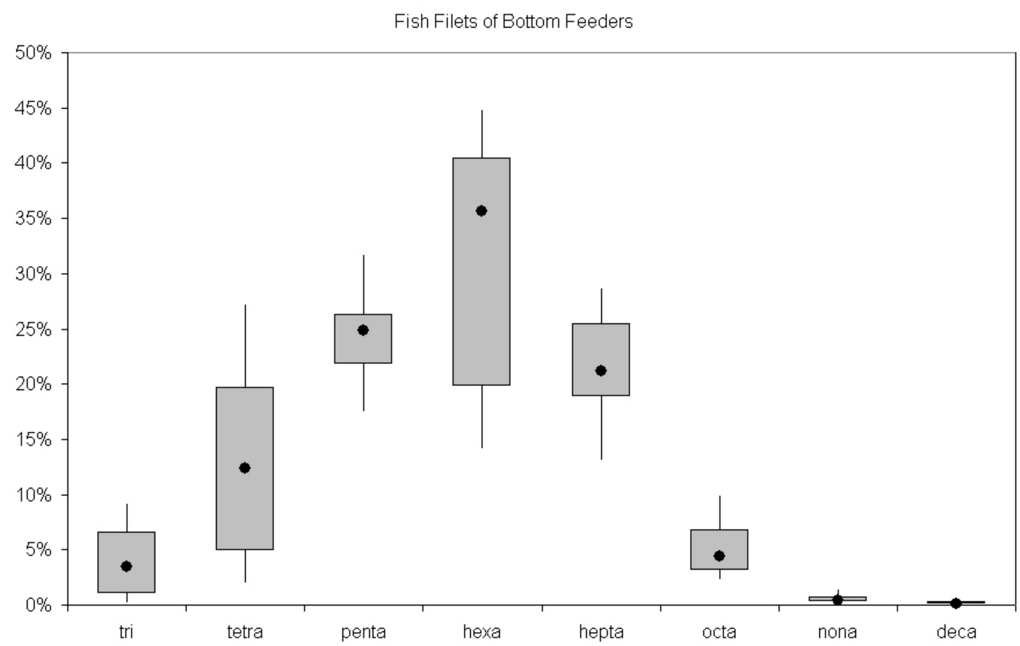


Figure 9. Distribution of PCB homologs in bottom sediments, as percent of $PCB_{3\text{-}10}$. Bars and whiskers indicate $5^{th}$%, $25^{th}$%, $75^{th}$%, and $95^{th}$% and solid circle indicates $50^{th}$% of 308 samples collected 2000-2005 and analyzed by George Mason University (Dr. Greg Foster), the Academy of Natural Sciences in Philadelphia (Dr. David Velinsky), or Chesapeake Biological Laboratory (Dr. Joel Baker) for multiple agencies. Percentages are calculated from homolog totals as reported by the laboratories. No attempt was made to correct for congener level contaminants as indicated by sample blanks. Collection sites range from the tidal fresh Potomac and the upper Anacostia River to the mouth of the Potomac estuary.

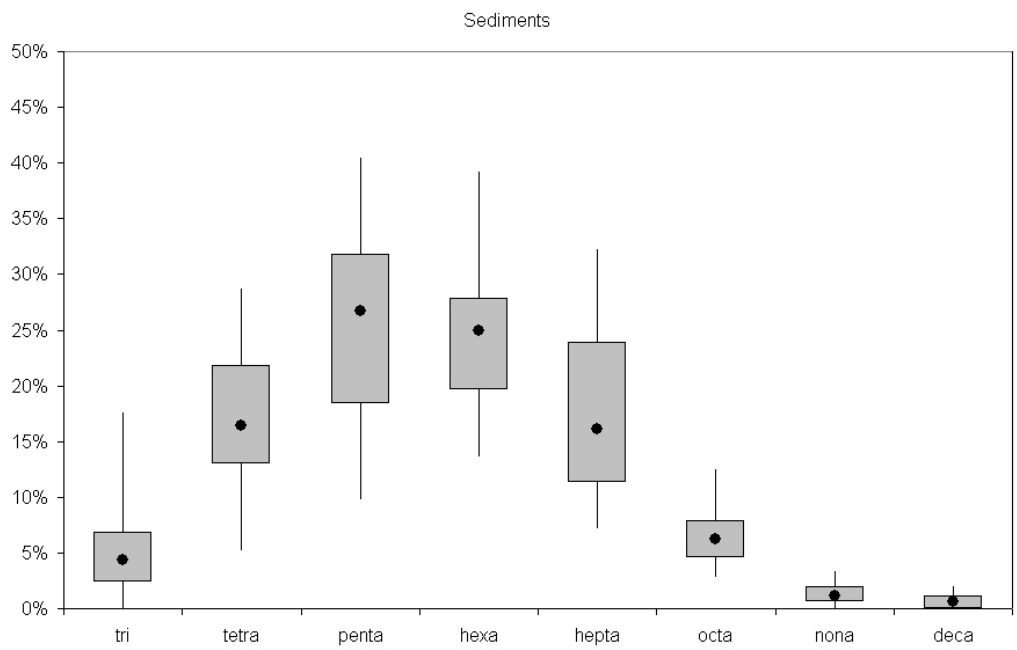


Figure 10. Distribution of PCB homologs in suspended particulates, as percent of $PCB_{3-10}$. Bars and whiskers indicate $5^{th}$%, $25^{th}$%, $75^{th}$%, and $95^{th}$% and solid circle indicates $50^{th}$% of 76 samples collected 2002-2005 and analyzed by the Academy of Natural Sciences in Philadelphia (Dr. David Velinsky) or Chesapeake Biological Laboratory (Dr. Joel Baker). Percentages are calculated from homolog totals as reported by the laboratories. No attempt was made to correct for congener level contaminants as indicated by sample blanks. Collection sites range from the tidal fresh Potomac and the upper Anacostia River to the mouth of the Potomac estuary.

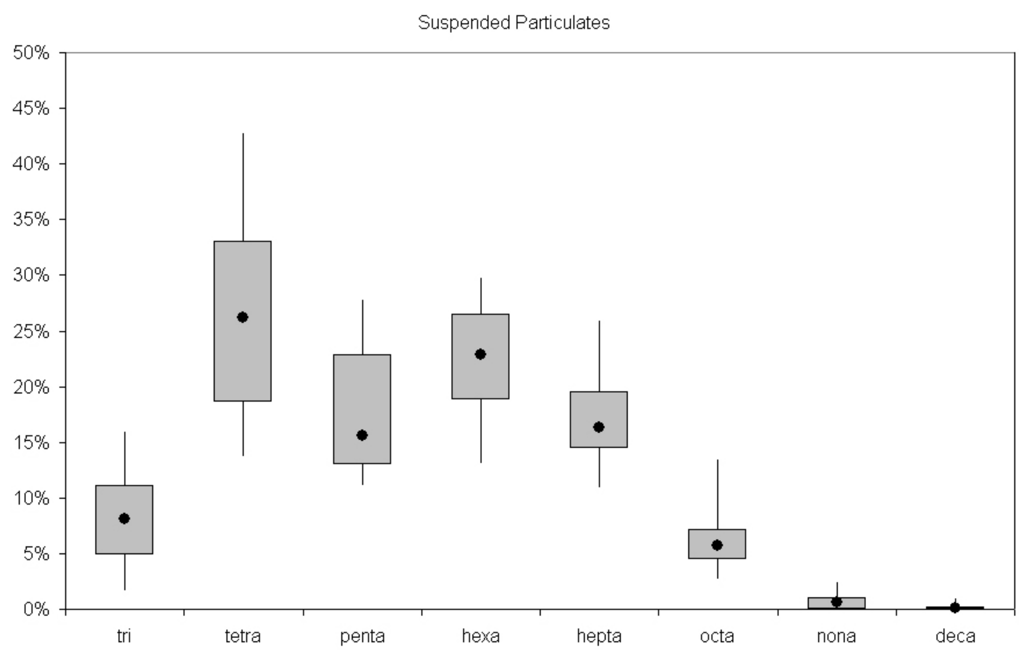


Figure 11. Distribution of PCB homologs dissolved in estuarine waters, as percent of $PCB_{3\text{-}10}$. Bars and whiskers indicate $5^{th}$%, $25^{th}$%, $75^{th}$%, and $95^{th}$% and solid circle indicates $50^{th}$% of 80 samples collected 2002-2005 and analyzed by the Academy of Natural Sciences in Philadelphia (Dr. David Velinsky) or Chesapeake Biological Laboratory (Dr. Joel Baker). Percentages are calculated from homolog totals as reported by the laboratories. No attempt was made to correct for congener level contaminants as indicated by sample blanks. Collection sites range from the tidal fresh Potomac and the upper Anacostia River to the mouth of the Potomac estuary.

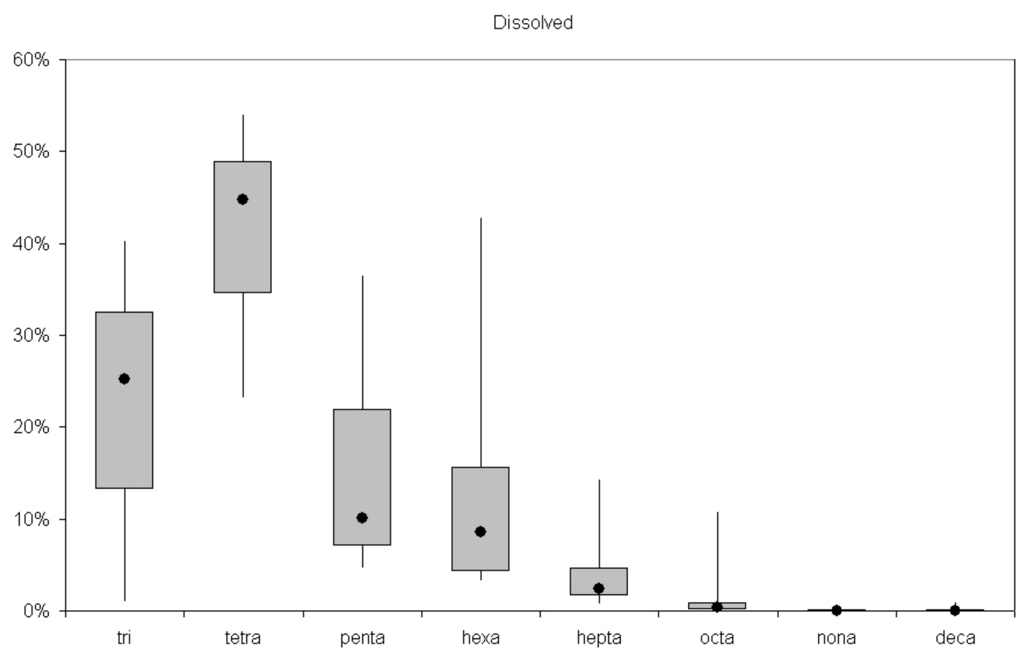


Figure 12. Distribution of PCB homologs in whole water (particulate + dissolved) from the Potomac River estuary, as percent of $PCB_{3\text{-}10}$. Bars and whiskers indicate $5^{th}$%, $25^{th}$%, $75^{th}$%, and $95^{th}$% and solid circle indicates $50^{th}$% of 81 samples collected 2002-2005 and analyzed by the Academy of Natural Sciences in Philadelphia (Dr. David Velinsky) or Chesapeake Biological Laboratory (Dr. Joel Baker). Percentages are calculated from homolog totals as reported by the laboratories. No attempt was made to correct for congener level contaminants as indicated by sample blanks. Collection sites range from the tidal fresh Potomac and the upper Anacostia River to the mouth of the Potomac estuary.

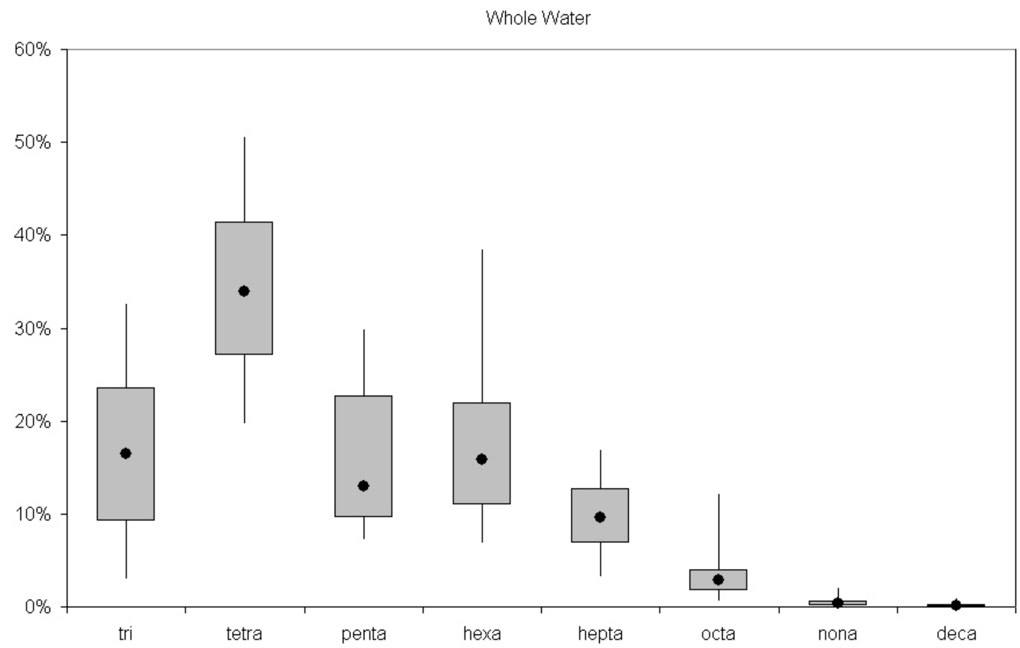


Figure 13. Comparison of observed total PCB (tPCB) concentrations and predicted concentrations derived from TSS-based and flow-based regressions, for the Anacostia Northeast and Northwest branches (Ana NE-NW), Watts Branch, and Potomac River at Chain Bridge (PRCB). Black line indicates 1:1 correspondence between observed and predicted tPCB concentrations. Dashed colored lines: regressions with TSS-based predicted concentrations. Solid colored lines: regressions with flow-based predicted concentrations. Two extremely low observed concentrations (<0.005 ng tPCB/liter) were excluded from the Anacostia regressions.

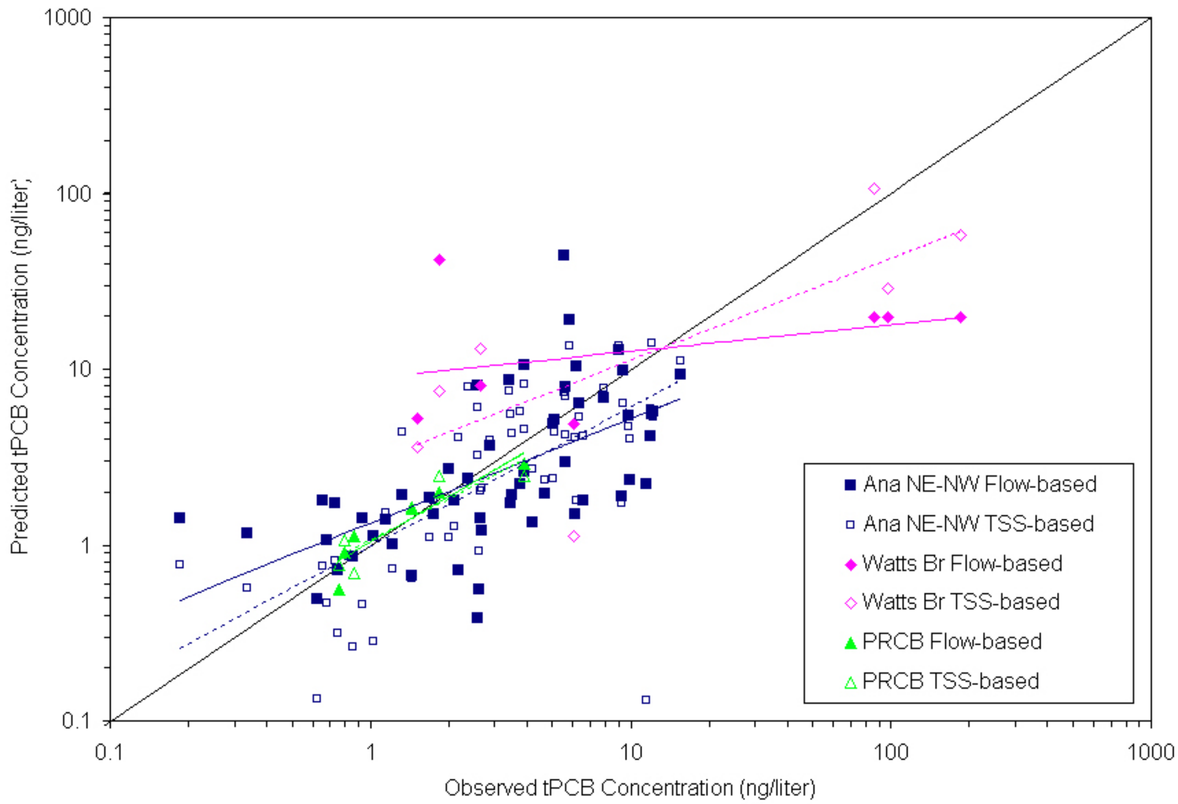


Figure 14. The $PCB_{3-10}$-TSS regressions with their underlying data. Symbols: DC Urban, red squares and line; Near DC, green diamonds and line; Chain Bridge, light blue asterisks and line; Else, dark blue triangles and line. See text for details. Note the scale is log-log.

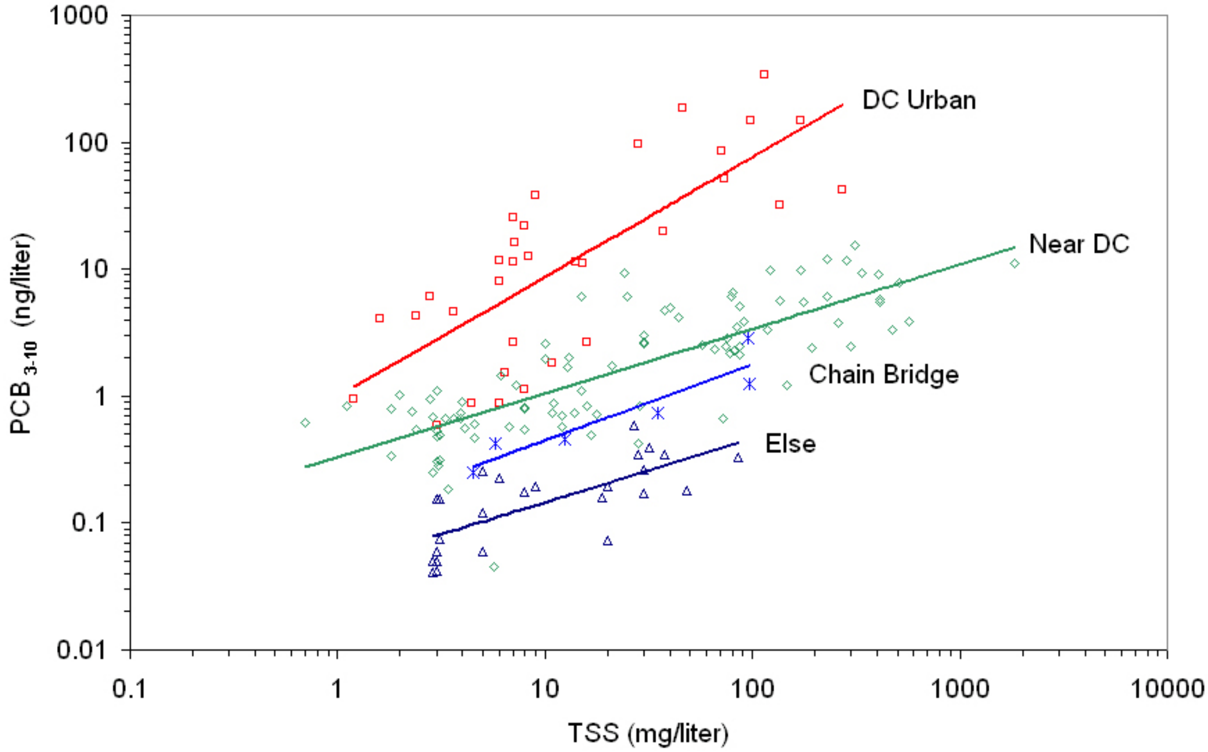


Figure 15. Comparison of TSS regressions with tPCB and $PCB_{3\text{-}10}$. Both PCB parameters are the sum of the particulate and dissolved fractions. tPCB includes all ten homologs and $PCB_{3\text{-}10}$ includes only homologs 3 - 10 ("tri-deca"). Note the scale is log-log.

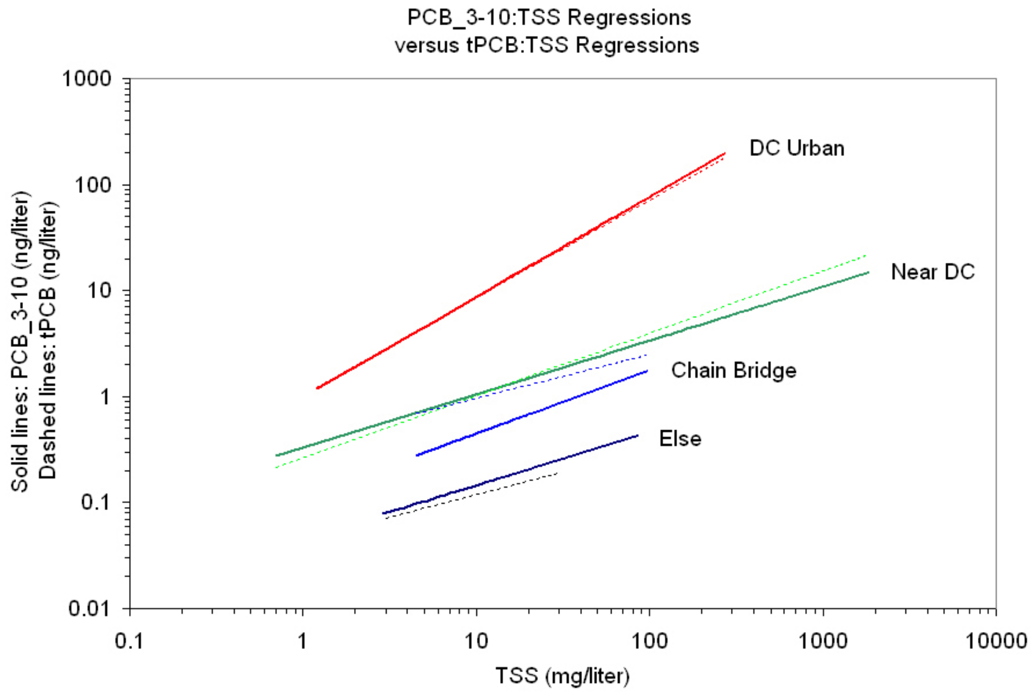


Figure 16: Average annual $PCB_{3-10}$ loads from tributaries. As described in the text, tributary loads are predicted by PCB:TSS regressions and Chesapeake Bay Watershed Model TSS values. Note the log scale for PCB.

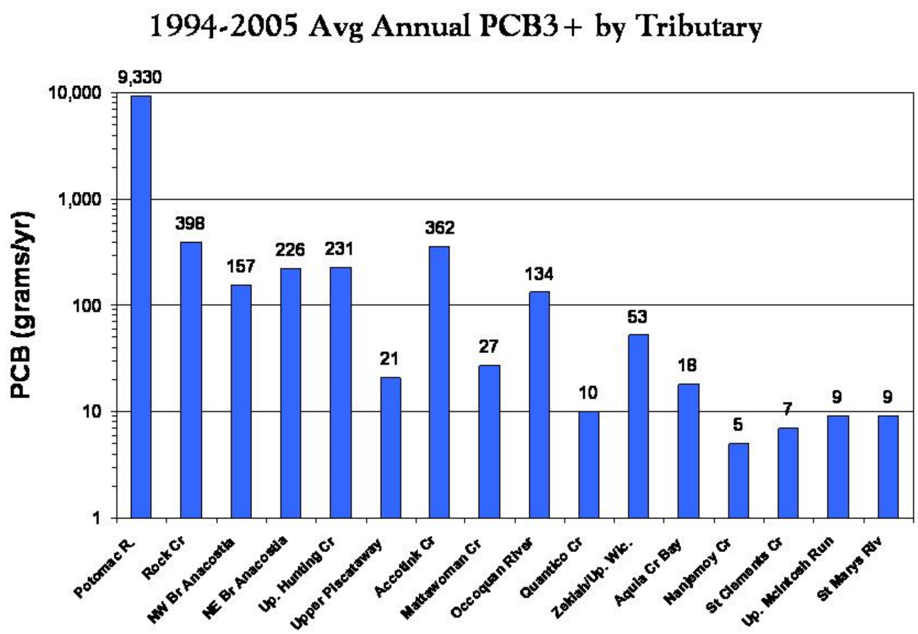


Figure 17. Location of 22 wastewater treatment plants tracked for loading inputs to the PCB model. The dark blue areas are tributary watersheds.

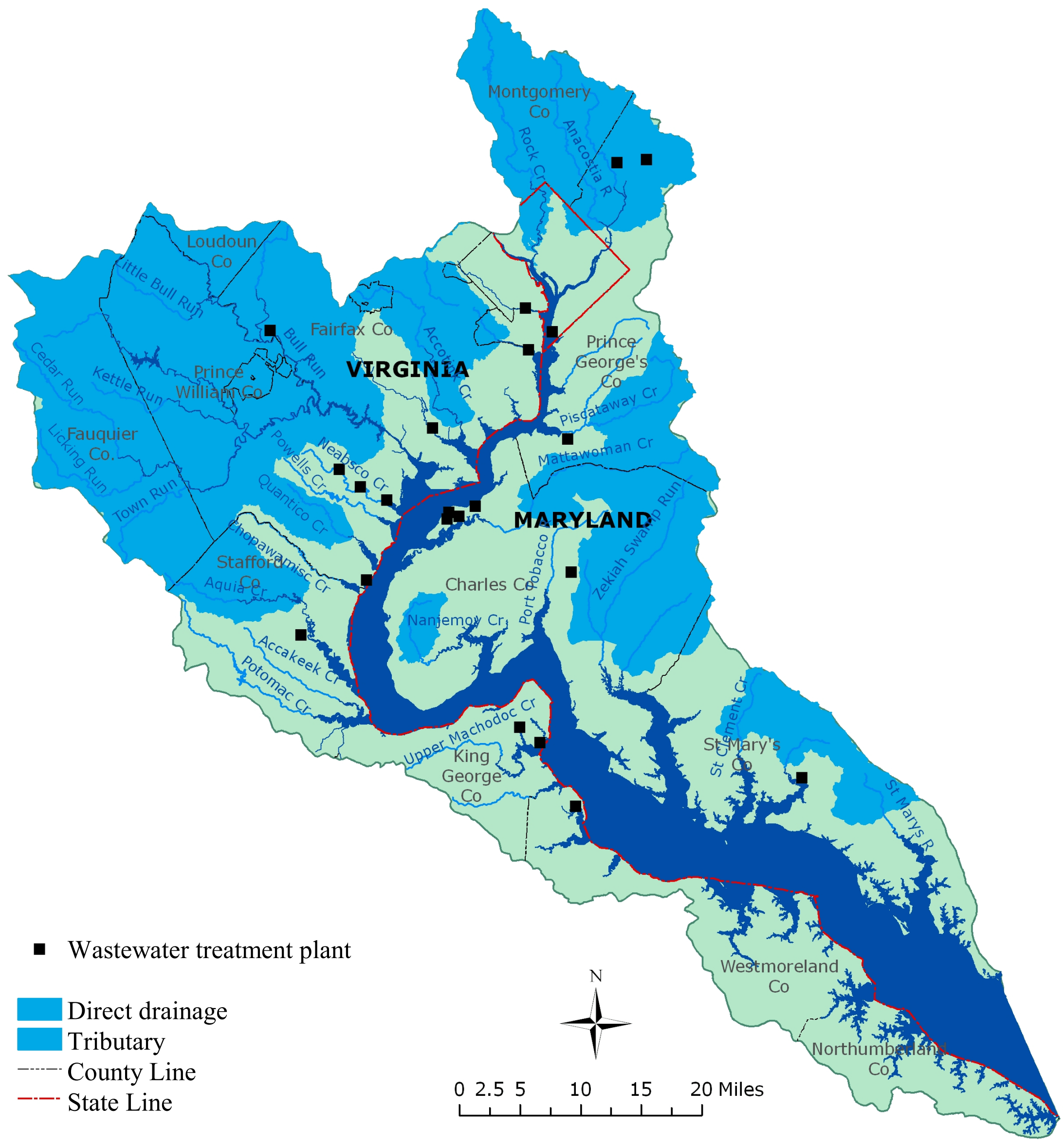


Figure 18. Location of PCB contaminated sites. These sites have been identified as potential sources of PCBs. See also Table 13.

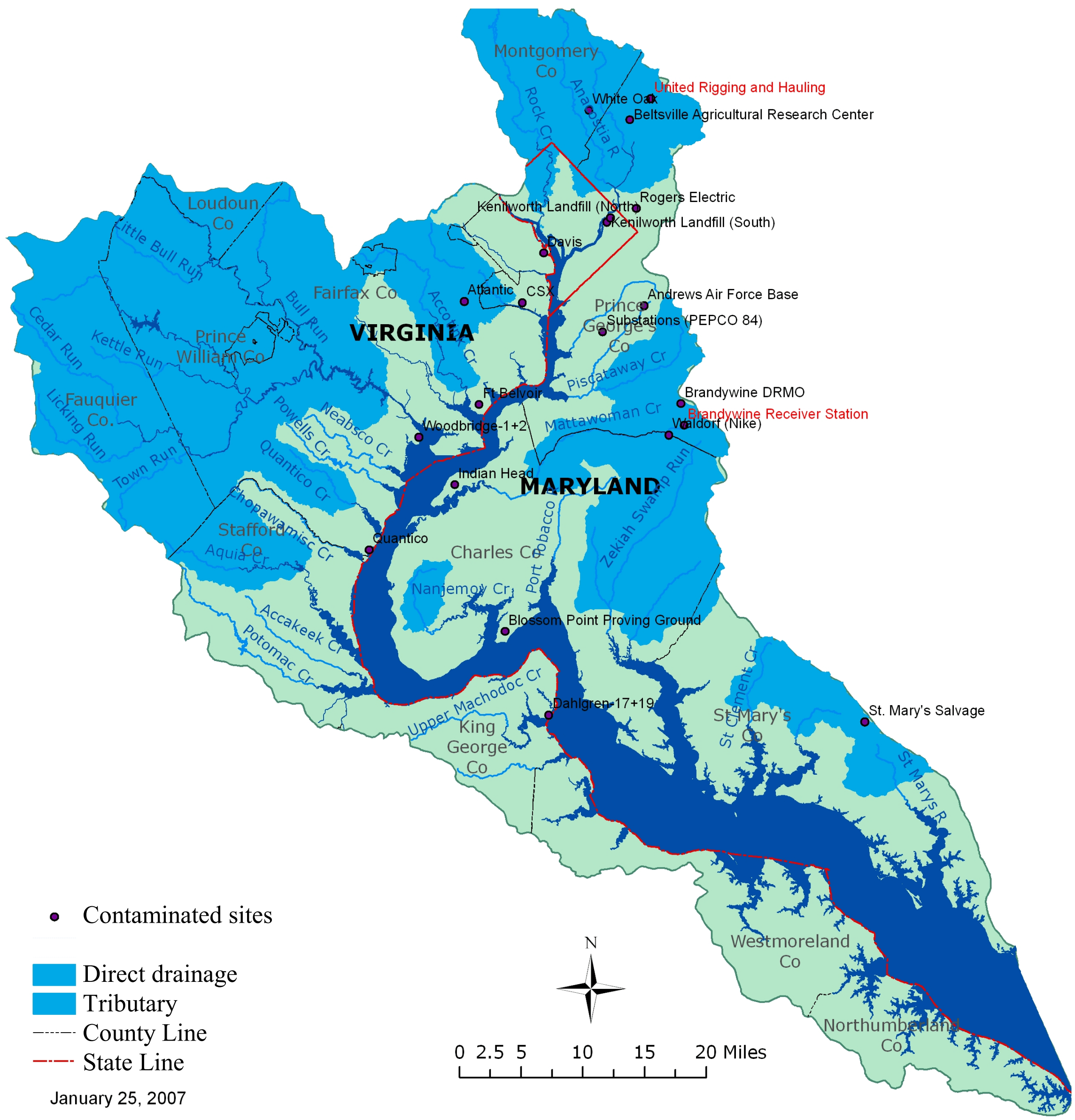


Figure 19. Atmospheric deposition zones.

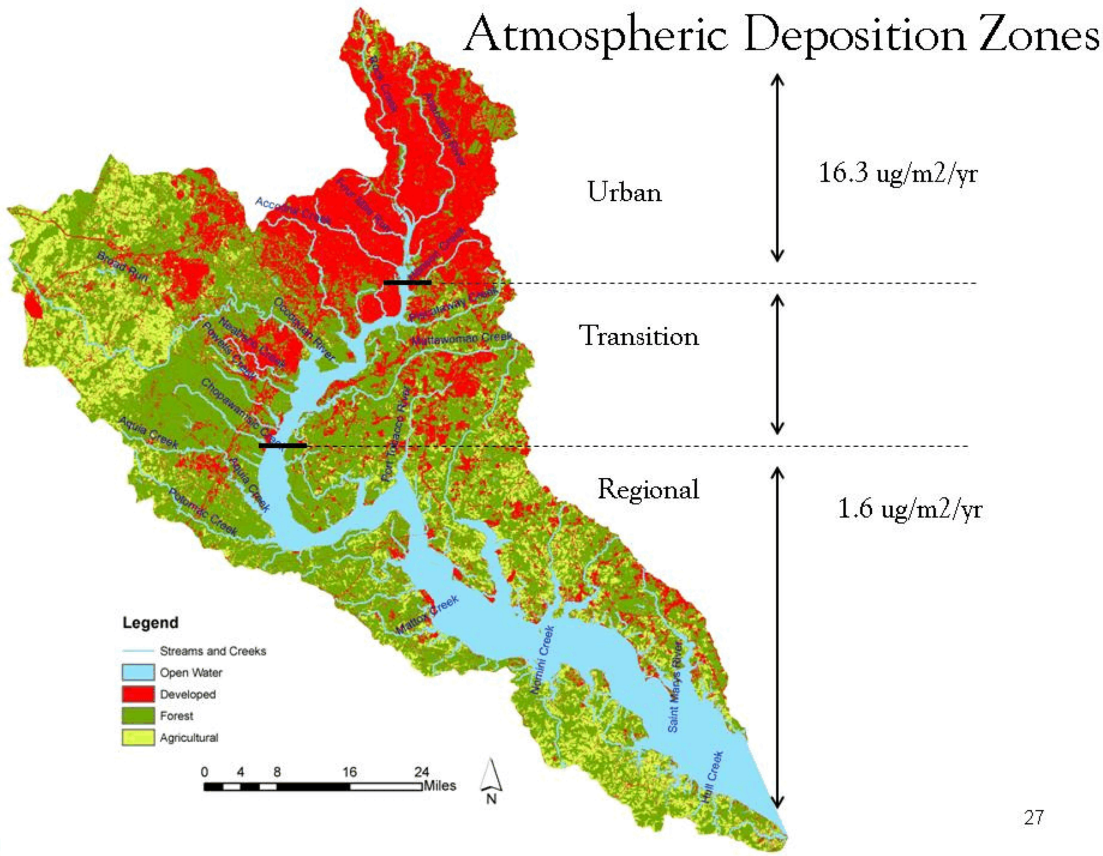
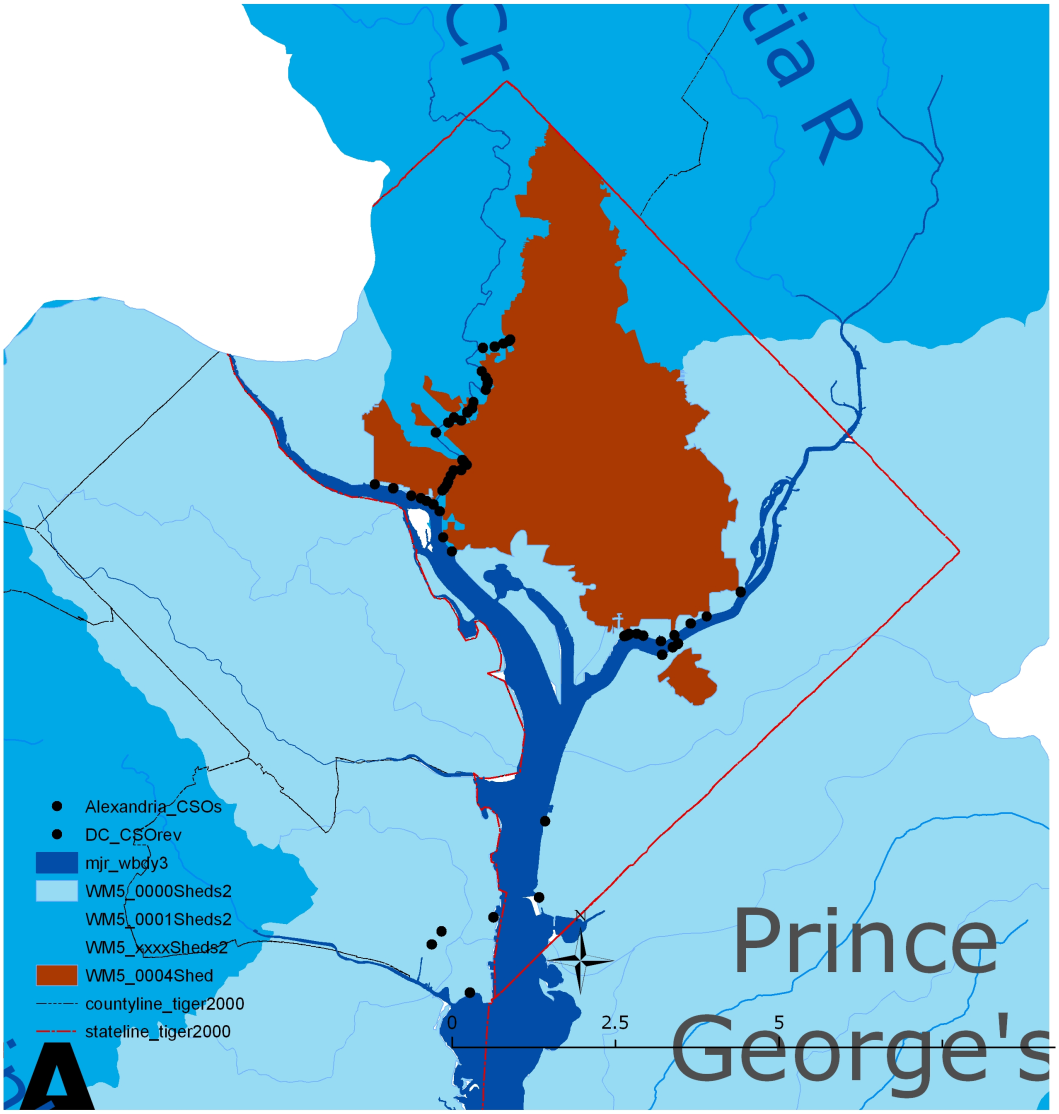


Figure 20. Location of Combined Sewer Overflow outfalls in the District of Columbia and in Alexandria



# APPENDIX B: TABLES

Table 1. Data sets used to examine pre 2000 and 2000-2003 PCB concentrations in Potomac estuary sediments.

| STUDY | BEGIN DATE | END DATE | SOURCE | PROJECT NAME |
|---|---|---|---|---|
| ANS_2000 | 1-Sep-00 | 1-Sep-00 | ANS-PCER; David Velinsky | Sediment Transport: Additional Chemical Analysis Study, Phase II |
| EMAP_1992 | 27-Jul-92 | 28-Aug-92 | EMAP-Estuaries Program Level Database; downloaded from CBP toxics database | Virginia Province 1992 Sediment Chemistry Data |
| EMAP_1993 | 1-Aug-93 | 11-Aug-93 | EMAP-Estuaries Program Level Database; downloaded from CBP toxics database | Virginian Province Sediment Chemistry Data |
| GMU_2000 | 1-Aug-00 | 1-Aug-00 | GMU; Phil McEachern | Hydrophobic Organic Compounds in Sediments of the Potomac River Watershed |
| GMU_2001 | 13-May-01 | 13-May-01 | George Mason University; Greg Foster provided data from a Masters project | Sediment Chemistry in DC Waters: Master's Project |
| ICPRB_1989 | 11-Oct-89 | 11-Oct-89 | ICPRB & LimnoTech, downloaded from CBP toxics database | Sediment Survey of Priority Pollutants in the District of Columbia Waters |
| NCA_ROUTINE | 1-Jan-01 | 3-Mar-04 | VADEQ Mark Richards | National Coastal Assessment Program |
| NOAA_1999 | 26-Aug-99 | 6-Sep-99 | NOAA; downloaded from CBP toxics database | 1999 NOAA Sediment Chemistry |
| QUAN_2002 | 25-Sep-02 | 1-Oct-02 | Quantico Marine Corps Combat Development Command (MCCDC); Kristen Stein | Final Quantico Watershed Post IRA Study |
| USEPA_1999 | 25-Oct-99 | 25-Oct-99 | USEPA; downloaded from CBP toxics database | Methods for the determination of chemical substances in marine and estuarine environmental samples |
| USEPA_USGS_1997 | 15-Sep-97 | 15-Sep-97 | USEPA/USGS; downloaded from CBP toxics database | Mid-Atlantic Integrated Assessment 1997 Chesapeake Bay Sediment Data |
| VADEQ_ROUTINE | 4-Jun-96 | 26-Sep-01 | VADEQ Mark Richards | Routine tributary sediment samples |

Table 2. Data sets used to examine pre 2000 and 2000-2003 PCB concentrations in Potomac estuary bottom feeding fish (carp, catfish, eel).

| STUDY | BEGIN DATE | END DATE | SOURCE | PROJECT NAME |
|---|---|---|---|---|
| EPA_1998 | 24-Jul-98 | 27-Jul-98 | CBP Toxics Database and also at EPA: http://www.epa.gov/emap/maia/html/data/estuary/9798/ | MAIA Estuaries 1998 Fish Tissue Data |
| FWS_2000 | 2-Nov-00 | 3-Nov-00 | FWS Fred Pinkney Publication No. CBFO-C01-01 | Analysis of Contaminant Concentrations in Fish Tissue Collected from the Water of the District of Columbia |
| ICPRB_1992 | 1-Jan-89 | 1-Jan-93 | ICPRB David Velinsky Report # 94-1 | Distribution of Chemical Contaminants in Wild Fish Species in Washington D.C. 1989-1992 |
| ICPRB_1995 | 1-Jan-93 | 1-Jan-95 | ICPRB David Velinsky Report # 96-1 | Distribution of Chemical Contaminants in 1993-95 Wild Fish Species in the District of Columbia |
| MDE_ROUTINE | 8-Feb-99 | 29-Oct-03 | CBL Joel Baker | Maryland Department of the Environment Fish Tissue Monitoring Program: 1999 - 2004 |
| NOAA_ROUTINE | 30-Jun-89 | 9-Jan-97 | CBP Toxics Database | NOAA National Status and Trends Program Mussel Watch Project Data, 1994-1997 |
| VADEQ_ROUTINE | 4-Jun-96 | 26-Sep-01 | VADEQ Mark Richards | VA DEQ Routine Tributary Sampling: 1996, 2000, 2001 |

Table 3. Tributary segments in the Chesapeake Watershed Model. WM5 river segment ID: "PL" designates the lower Potomac River watersheds; the middle four digits are a unique watershed identifier; the last four digits indicate whether the watershed drains directly into the Potomac River estuary (0000) or drains to a tributary of the Potomac (0001).

| **Tributary Name** | **WM5 riverseg ID** | **Area (sq. mi.)** |
|---|---|---|
| NW Br Anacostia | PL0_4510_0001 | 51.9 |
| NE Br Anacostia | PL1_4540_0001 | 74.7 |
| Rock Cr | PL1_4780_0001 | 70.3 |
| Upper Hunting Creek | PL0_5000_0001 | 34.6 |
| Upper Piscataway | PL0_5070_0001 | 38.6 |
| Accotink Cr | PL1_5130_0001 | 50.3 |
| Mattawoman Creek | PL1_5230_0001 | 54.9 |
| Occoquan River | PL0_5250_0001 | 354.1 |
| Quantico Cr | PL0_5490_0001 | 27.0 |
| Trib to Upper Wicomico Bay | PL0_5510_0001 | 42.1 |
| Middle Zekiah Swamp Run | PL2_5630_0001 | 86.5 |
| Aquia Cr Bay | PL1_5690_0001 | 50.7 |
| Trib. To Zekiah Swamp Run | PL0_5710_0001 | 14.7 |
| Nanjemoy Creek | PL0_5720_0001 | 15.0 |
| St Clements Cr | PL0_5750_0001 | 18.0 |
| Upper McIntosh Run | PL0_5830_0001 | 28.7 |
| St Marys River | PL1_5910_0001 | 24.1 |
| **Total area of tributaries excl. Potomac river** | | **1,036.2** |
| | | |
| Potomac R. at Chain Br. | PM7_4820_0001 | 11,560.0 |

Table 4. Average percentage of each homolog in $PCB_{3\text{-}10}$ in whole water (dissolved + particulate) for tributaries to the Potomac estuary. Highlighted values are the dominant homolog(s). Percentages are calculated from homolog totals as reported by the laboratories. No attempt was made to correct for congener level contaminants as indicated by sample blanks.

| State/Tributary | | n | tri | tetra | penta | hexa | hepta | octa | nona | deca |
|---|---|---|---|---|---|---|---|---|---|---|
| DC | Hickey Run | 11 | 10% | 25% | 26% | 24% | 11% | 3% | 1% | 0% |
| DC | Little Beaverdam Creek | 9 | 13% | 51% | 21% | 10% | 4% | 1% | 1% | 0% |
| DC | Watts Branch | 8 | 8% | 25% | 35% | 21% | 7% | 2% | 2% | 0% |
| DC | Misc. DC Tributaries | 15 | 17% | 31% | 17% | 19% | 11% | 4% | 1% | 0% |
| MD | Anacostia NE Branch | 44 | 12% | 31% | 29% | 17% | 9% | 2% | 1% | 0% |
| MD | Anacostia NW Branch | 40 | 19% | 36% | 27% | 9% | 6% | 2% | 1% | 0% |
| MD | Mattawoman Creek | 2 | 19% | 24% | 28% | 18% | 6% | 2% | 2% | 1% |
| MD | Piscataway Creek | 2 | 26% | 21% | 25% | 16% | 7% | 2% | 1% | 1% |
| MD | Potomac @ Chain Bridge | 6 | 14% | 27% | 21% | 16% | 16% | 5% | 1% | 0% |
| VA | Aquia Creek | 2 | 21% | 8% | 29% | 26% | 10% | 6% | 0% | 0% |
| VA | Chopawamsic Creek | 3 | 31% | 13% | 24% | 26% | 6% | 0% | 0% | 0% |
| VA | Coan Mill Stream | 2 | 14% | 23% | 35% | 18% | 6% | 1% | 1% | 2% |
| VA | Dogue Creek | 2 | 17% | 19% | 30% | 21% | 9% | 2% | 1% | 1% |
| VA | Four Mile Run | 2 | 9% | 17% | 45% | 17% | 9% | 2% | 1% | 0% |
| VA | Giles Run | 3 | 30% | 17% | 17% | 22% | 11% | 2% | 0% | 0% |
| VA | Hunting Creek | 3 | 25% | 19% | 31% | 15% | 6% | 3% | 1% | 0% |
| VA | Little Hunting Creek | 2 | 22% | 22% | 25% | 20% | 9% | 2% | 1% | 0% |
| VA | Monroe Creek | 2 | 9% | 17% | 33% | 24% | 8% | 3% | 3% | 3% |
| VA | Occoquan River | 1 | 13% | 20% | 27% | 15% | 11% | 4% | 3% | 7% |
| VA | Pohick Creek | 2 | 10% | 12% | 30% | 19% | 5% | 15% | 5% | 4% |
| VA | Potomac Creek | 2 | 12% | 8% | 24% | 19% | 16% | 19% | 0% | 2% |
| VA | Quantico Creek | 3 | 24% | 10% | 35% | 13% | 8% | 11% | 0% | 0% |
| VA | Upper Machodoc Creek | 2 | 7% | 8% | 24% | 21% | 4% | 32% | 0% | 3% |
| VA | Williams Creek | 2 | 3% | 11% | 41% | 33% | 3% | 7% | 1% | 2% |

Table 5. The regression coefficient ($r^2$) and statistical significance of log-log regressions between dissolved (Diss.), particulate (Part.) and total PCB, in pg/liter, and the water quality parameters dissolved organic carbon (DOC), particulate carbon (PC), total organic carbon (TOC), and total suspended solids/particles (TSS), in mg/liter (**, p<0.01; *, p<0.05, ns, p≥0.05; –, no data). Sample size indicated in parentheses (zero values or blanks removed from analysis). Laboratories: GMU, George Mason University (Dr. Greg Foster); ANS, Academy of Natural Sciences in Philadelphia (Dr. David Velinsky); CBL, Chesapeake Biological Laboratory (Dr. Joel Baker); GERG, Geochemical and Environmental Research Group at Texas A&M University (Dr. Terry Wade). Sampling locations: Northeast Branch of the Anacostia River, MD; Northwest Branch of the Anacostia River, MD; District of Columbia tributaries to the Anacostia River, DC; Potomac River at Chain Bridge; Virginia tributaries to the Potomac River >20 km away from Washington, DC.

| | Laboratory and Sampling Location | | | | |
|---|---|---|---|---|---|
| Relationship | GMU Anacostia NE-NW Br. | GMU Anacostia DC | ANS Anacostia NE-NW Br. | CBL Potomac @ CB | GERG "Far" VA tribs |
| Diss. PCB - DOC | -- | -- | ns (24) | -- | -- |
| Diss. PCB - PC | -- | -- | ns (25) | ns (6) | -- |
| Diss. PCB - TOC | -- | -- | ns (24) | -- | -- |
| Diss. PCB - TSS | 0.14 ** (50) | 0.19 * (24) | ns (25) | ns (6) | -- |
| Part. PCB - DOC | -- | -- | ns (22) | -- | -- |
| Part. PCB - PC | -- | -- | 0.7 ** (23) | 0.81 * (6) | -- |
| Part. PCB - TOC | -- | -- | 0.70 ** (22) | -- | -- |
| Part. PCB - TSS | 0.59 ** (54) | 0.46 ** (23) | 0.83 ** (23) | 0.86 ** (6) | -- |
| Total PCB - DOC | -- | -- | ns (24) | -- | 0.40 * (11) |
| Total PCB - PC | -- | -- | 0.24 ** (25) | 0.69 * (6) | -- |
| Total PCB - TOC | -- | -- | 0.24 * (24) | -- | 0.45 * (12) |
| Total PCB - TSS | 0.51 ** (56) | 0.63 ** (24) | 0.32 ** (25) | 0.78 * (6) | 0.35 * (12) |

Table 6. Analysis of variance for the multiple linear regression models predicting total PCB concentration from TSS and flow in the Anacostia NE and NW branches. PCB, ng $liter^{-1}$; TSS, mg $liter^{-1}$; flow, cubic feet $sec^{-1}$. Terms added sequentially (first to last).

| | df | Sum of Sq | Mean Sq | F Value | Pr(F) | |
|---|---|---|---|---|---|---|
| Model (1): PCB = f (TSS, flow) | | | | | | |
| TSS | 1 | 206.2165 | 206.2165 | 21.40966 | <0.0001 | highly significant |
| Flow | 1 | 21.3698 | 21.3698 | 2.21864 | 0.142 | not significant |
| Residuals | 53 | 510.4926 | 9.6319 | | | |
| Model (2): log PCB = f (log TSS, log flow) | | | | | | |
| log TSS | 1 | 14.19510 | 14.19510 | 57.80973 | <0.0001 | highly significant |
| log Flow | 1 | 0.38713 | 0.38713 | 1.57658 | 0.215 | not significant |
| Residuals | 53 | 13.01408 | 0.24555 | | | |

Table 7. Linkage of Ches. Bay Watershed Model tributaries to the Potomac PCB / DynHyd model. Watershed segment and unique ID are tributary designations in the Chesapeake Bay Watershed Model (CBWM), one of five linked models in the Chesapeake Bay Environmental Model Package (CBEMP). CH3D is the estuarine model cell designation in the Chesapeake Bay Hydrodynamic Model (CH3D), another component of the CBEMP. DH is the DynHyd model cell designation. DH Fraction is the flow-based apportionment of tributary loads from CH3D cell. PCB Code refers to the algorithms used to estimate PCB concentrations from TSS concentrations. See Table 1 heading for more detail.

| Tributary Name | Watershed Segment | Unique ID | CH3D model cell | DH model cell | DH Fraction | PCB Code |
|---|---|---|---|---|---|---|
| Potomac R. at Chain Br. | PM7_4820_0001 | 4820 | 2106 | 97 | 1 | ChainBr |
| NW Br Anacostia River | PL0_4510_0001 | 4510 | 2111 | 246 | 0.41 | NearDC |
| NE Br Anacostia River | PL1_4540_0001 | 4540 | 2111 | 247 | 0.59 | NearDC |
| Rock Creek | PL1_4780_0001 | 4780 | 7108 | 87 | 1 | NearDC |
| Upper Hunting Creek | PL0_5000_0001 | 5000 | 18105 | 207 | 1 | NearDC |
| Upper Piscataway Creek | PL0_5070_0001 | 5070 | 26114 | 203 | 1 | Else |
| Accotink Creek | PL1_5130_0001 | 5130 | 30102 | 199 | 1 | NearDC |
| Occoquan River | PL0_5250_0001 | 5250 | 36096 | 185 | 1 | Else |
| Mattawoman Creek | PL1_5230_0001 | 5230 | 40116 | 179 | 1 | Else |
| Quantico Creek | PL0_5490_0001 | 5490 | 44100 | 173 | 1 | Else |
| Aquia Creek | PL1_5690_0001 | 5690 | 52097 | 171 | 1 | Else |
| Nanjemoy Creek | PL0_5720_0001 | 5720 | 60114 | 164 | 1 | Else |
| Trib. To Zekiah Swamp Run | PL0_5710_0001 | 5710 | 78120 | 150 | 0.15 | Else |
| Middle Zekiah Swamp Run | PL2_5630_0001 | 5630 | 78120 | 150 | 0.85 | Else |
| Trib to Upper Wicomico Bay | PL0_5510_0001 | 5510 | 79120 | 150 | 1 | Else |
| St Clements Creek | PL0_5750_0001 | 5750 | 83116 | 143 | 1 | Else |
| Upper McIntosh Run | PL0_5830_0001 | 5830 | 85117 | 136 | 1 | Else |
| St Marys River | PL1_5910_0001 | 5910 | 104124 | 114 | 1 | Else |

Table 8. Chesapeake Bay Hydrodynamic Model (CH3D) cells mapped to POTPCB Model DynHyd (DH) cells. DH fraction indicates the fraction of the direct drainage watershed flow and load entering the CH3D cell that is apportioned to the DH cell. PCB Code refers to one of four TSS-$PCB_{3\text{-}10}$ regressions used to estimate $PCB_{3\text{-}10}$ concentrations from TSS concentrations (see text for details).

| CH3D | DH | DH Fraction | PCB Code |
|---|---|---|---|
| 2106 | 96 | 0.5 | NearDC |
| 2106 | 97 | 0.5 | NearDC |
| 2111 | 242 | 0.25 | DCUrban |
| 2111 | 243 | 0.25 | DCUrban |
| 2111 | 244 | 0.25 | DCUrban |
| 2111 | 245 | 0.25 | DCUrban |
| 2111 | 246 | 0 | DCUrban |
| 2111 | 247 | 0 | DCUrban |
| 3106 | 94 | 0.5 | NearDC |
| 3106 | 95 | 0.5 | NearDC |
| 3111 | 236 | 0.1667 | DCUrban |
| 3111 | 237 | 0.1667 | DCUrban |
| 3111 | 238 | 0.1667 | DCUrban |
| 3111 | 239 | 0.1667 | DCUrban |
| 3111 | 240 | 0.1667 | DCUrban |
| 3111 | 241 | 0.1667 | DCUrban |
| 4106 | 92 | 0.5 | NearDC |
| 4106 | 93 | 0.5 | NearDC |
| 4107 | 92 | 0.5 | NearDC |
| 4107 | 93 | 0.5 | NearDC |
| 4108 | 92 | 0.5 | NearDC |
| 4108 | 93 | 0.5 | NearDC |
| 4111 | 232 | 0.25 | DCUrban |
| 4111 | 233 | 0.25 | DCUrban |
| 4111 | 234 | 0.25 | DCUrban |
| 4111 | 235 | 0.25 | DCUrban |
| 5106 | 90 | 0.5 | NearDC |
| 5106 | 91 | 0.5 | NearDC |
| 5108 | 90 | 0.5 | NearDC |
| 5108 | 91 | 0.5 | NearDC |
| 5111 | 229 | 0.333 | DCUrban |
| 5111 | 230 | 0.333 | DCUrban |
| 5111 | 231 | 0.334 | DCUrban |
| 6106 | 88 | 0.5 | NearDC |
| 6106 | 89 | 0.5 | NearDC |
| 6108 | 88 | 0.5 | NearDC |
| 6108 | 89 | 0.5 | NearDC |
| 6111 | 226 | 0.25 | DCUrban |
| 6111 | 227 | 0.25 | DCUrban |
| 6111 | 228 | 0.25 | DCUrban |
| 6111 | 248 | 0.25 | DCUrban |
| 7106 | 86 | 0.5 | DCUrban |
| 7106 | 87 | 0.5 | DCUrban |
| 7108 | 87 | 1 | NearDC |
| 7111 | 223 | 0.333 | DCUrban |
| 7111 | 224 | 0.333 | DCUrban |
| 7111 | 225 | 0.334 | DCUrban |
| 8106 | 84 | 0.5 | DCUrban |
| 8106 | 85 | 0.5 | DCUrban |
| 8108 | 84 | 0.5 | DCUrban |
| 8108 | 85 | 0.5 | DCUrban |
| 8111 | 219 | 0.25 | DCUrban |
| 8111 | 220 | 0.25 | DCUrban |
| 8111 | 221 | 0.25 | DCUrban |
| 8111 | 222 | 0.25 | DCUrban |
| 9106 | 82 | 0.5 | DCUrban |
| 9106 | 83 | 0.5 | DCUrban |
| 9108 | 82 | 0.1 | DCUrban |
| 9108 | 83 | 0.4 | DCUrban |
| 9108 | 251 | 0.4 | DCUrban |
| 9111 | 214 | 0.2 | DCUrban |
| 9111 | 215 | 0.2 | DCUrban |
| 9111 | 216 | 0.2 | DCUrban |
| 9111 | 217 | 0.2 | DCUrban |
| 9111 | 218 | 0.2 | DCUrban |
| 10106 | 80 | 0.5 | DCUrban |
| 10106 | 81 | 0.5 | DCUrban |
| 10108 | 80 | 0.1 | DCUrban |
| 10108 | 81 | 0.2 | DCUrban |
| 10108 | 249 | 0.3 | DCUrban |
| 10108 | 250 | 0.4 | DCUrban |
| 10111 | 211 | 0.334 | DCUrban |
| 10111 | 212 | 0.333 | DCUrban |
| 10111 | 213 | 0.333 | DCUrban |
| 11106 | 79 | 1 | DCUrban |
| 11109 | 79 | 1 | DCUrban |
| 11110 | 79 | 1 | DCUrban |
| 11111 | 79 | 1 | DCUrban |
| 12106 | 78 | 1 | DCUrban |
| 12111 | 78 | 1 | NearDC |
| 13105 | 210 | 1 | NearDC |
| 13111 | 77 | 1 | NearDC |
| 14106 | 76 | 1 | NearDC |
| 14111 | 76 | 1 | NearDC |
| 15106 | 75 | 1 | NearDC |
| 15111 | 75 | 1 | NearDC |
| 16106 | 74 | 1 | NearDC |
| 16112 | 208 | 1 | NearDC |
| 16113 | 209 | 1 | NearDC |
| 17106 | 73 | 1 | NearDC |
| 17111 | 73 | 1 | NearDC |
| 18105 | 207 | 1 | NearDC |
| 18112 | 206 | 1 | NearDC |
| 19105 | 207 | 1 | NearDC |
| 19112 | 72 | 0 | NearDC |
| 19112 | 206 | 1 | NearDC |
| 20106 | 71 | 1 | NearDC |
| 20111 | 71 | 1 | NearDC |
| 21106 | 70 | 1 | NearDC |
| 21111 | 70 | 1 | NearDC |
| 22106 | 69 | 1 | NearDC |

| CH3D | DH | DH Fraction | PCB Code |
|---|---|---|---|
| 22112 | 205 | 1 | NearDC |
| 23106 | 68 | 1 | NearDC |
| 23111 | 68 | 1 | NearDC |
| 24106 | 67 | 1 | NearDC |
| 24111 | 67 | 1 | NearDC |
| 25106 | 66 | 1 | NearDC |
| 25111 | 66 | 1 | NearDC |
| 26104 | 204 | 1 | NearDC |
| 26105 | 65 | 1 | NearDC |
| 26112 | 201 | 1 | Else |
| 26113 | 202 | 1 | Else |
| 26114 | 203 | 1 | Else |
| 27105 | 64 | 1 | NearDC |
| 27111 | 64 | 1 | Else |
| 28105 | 63 | 1 | NearDC |
| 28111 | 63 | 1 | Else |
| 29104 | 200 | 1 | NearDC |
| 29111 | 62 | 1 | Else |
| 30102 | 199 | 1 | Else |
| 30105 | 61 | 1 | NearDC |
| 30111 | 61 | 1 | Else |
| 31101 | 198 | 1 | Else |
| 31102 | 197 | 1 | Else |
| 31103 | 196 | 1 | Else |
| 31104 | 195 | 1 | Else |
| 31111 | 60 | 1 | Else |
| 32105 | 59 | 1 | Else |
| 32111 | 59 | 1 | Else |
| 33105 | 58 | 1 | Else |
| 33111 | 58 | 1 | Else |
| 34098 | 186 | 0.5 | Else |
| 34098 | 194 | 0.5 | Else |
| 34103 | 57 | 1 | Else |
| 34104 | 57 | 1 | Else |
| 34111 | 57 | 1 | Else |
| 35098 | 193 | 1 | Else |
| 35103 | 56 | 1 | Else |
| 35111 | 56 | 1 | Else |
| 36096 | 185 | 0.333 | Else |
| 36096 | 192 | 0.667 | Else |
| 36097 | 191 | 1 | Else |
| 36098 | 190 | 1 | Else |
| 36099 | 189 | 1 | Else |
| 36100 | 188 | 1 | Else |
| 36101 | 187 | 1 | Else |
| 36102 | 55 | 1 | Else |
| 36111 | 55 | 1 | Else |
| 37099 | 189 | 1 | Else |
| 37111 | 54 | 1 | Else |
| 38099 | 189 | 1 | Else |
| 38100 | 188 | 1 | Else |
| 38101 | 181 | 0.05 | Else |
| 38101 | 182 | 0.1 | Else |
| 38101 | 183 | 0.2 | Else |
| 38101 | 184 | 0.65 | Else |
| 38111 | 53 | 1 | Else |
| 39102 | 52 | 1 | Else |
| 39111 | 52 | 1 | Else |
| 40101 | 180 | 1 | Else |
| 40112 | 175 | 1 | Else |
| 40113 | 176 | 1 | Else |
| 40114 | 177 | 1 | Else |
| 40115 | 178 | 1 | Else |
| 40116 | 179 | 1 | Else |
| 41102 | 50 | 1 | Else |
| 41111 | 50 | 1 | Else |
| 41111 | 51 | 0 | Else |
| 42102 | 49 | 1 | Else |
| 42111 | 49 | 1 | Else |
| 43102 | 48 | 1 | Else |
| 43112 | 174 | 1 | Else |
| 44100 | 173 | 1 | Else |
| 44101 | 172 | 1 | Else |
| 44111 | 47 | 1 | Else |
| 45102 | 46 | 1 | Else |
| 45111 | 46 | 1 | Else |
| 46101 | 257 | 0.05 | Else |
| 46101 | 258 | 0.95 | Else |
| 46111 | 45 | 1 | Else |
| 47101 | 44 | 1 | Else |
| 47111 | 44 | 1 | Else |
| 48101 | 43 | 1 | Else |
| 48111 | 43 | 1 | Else |
| 49101 | 42 | 1 | Else |
| 49111 | 42 | 1 | Else |
| 50101 | 41 | 1 | Else |
| 50111 | 41 | 1 | Else |
| 51101 | 40 | 1 | Else |
| 51111 | 40 | 1 | Else |
| 52097 | 171 | 1 | Else |
| 52098 | 170 | 1 | Else |
| 52099 | 169 | 1 | Else |
| 52100 | 168 | 1 | Else |
| 52111 | 39 | 1 | Else |
| 53100 | 168 | 1 | Else |
| 53111 | 39 | 1 | Else |
| 54101 | 38 | 1 | Else |
| 54111 | 38 | 1 | Else |
| 55098 | 167 | 1 | Else |
| 55099 | 166 | 1 | Else |
| 55100 | 165 | 1 | Else |
| 55111 | 37 | 1 | Else |
| 56101 | 36 | 1 | Else |
| 56111 | 36 | 1 | Else |
| 57101 | 35 | 1 | Else |
| 57111 | 35 | 1 | Else |
| 58101 | 34 | 1 | Else |
| 58111 | 34 | 1 | Else |
| 59101 | 33 | 1 | Else |
| 59111 | 33 | 1 | Else |
| 60101 | 32 | 1 | Else |
| 60111 | 32 | 1 | Else |
| 60114 | 164 | 1 | Else |

| CH3D | DH | DH Fraction | PCB Code |
|---|---|---|---|
| 61101 | 31 | 1 | Else |
| 61111 | 31 | 1 | Else |
| 61114 | 163 | 1 | Else |
| 62101 | 30 | 1 | Else |
| 62112 | 160 | 1 | Else |
| 62113 | 161 | 1 | Else |
| 62114 | 162 | 1 | Else |
| 63100 | 29 | 1 | Else |
| 63111 | 29 | 1 | Else |
| 64100 | 28 | 1 | Else |
| 64101 | 28 | 1 | Else |
| 64102 | 28 | 1 | Else |
| 64112 | 28 | 1 | Else |
| 65103 | 27 | 1 | Else |
| 65112 | 27 | 1 | Else |
| 66103 | 26 | 1 | Else |
| 66113 | 156 | 1 | Else |
| 66114 | 157 | 1 | Else |
| 66115 | 158 | 1 | Else |
| 66116 | 159 | 1 | Else |
| 67103 | 25 | 1 | Else |
| 67110 | 25 | 1 | Else |
| 67111 | 25 | 1 | Else |
| 67112 | 25 | 1 | Else |
| 68099 | 22 | 1 | Else |
| 68102 | 24 | 1 | Else |
| 68109 | 24 | 1 | Else |
| 69099 | 22 | 1 | Else |
| 69102 | 23 | 1 | Else |
| 69109 | 23 | 1 | Else |
| 70097 | 155 | 1 | Else |
| 70098 | 154 | 1 | Else |
| 70100 | 22 | 1 | Else |
| 70101 | 22 | 1 | Else |
| 70110 | 22 | 1 | Else |
| 71099 | 21 | 1 | Else |
| 71111 | 21 | 1 | Else |
| 72099 | 255 | 0.1 | Else |
| 72099 | 256 | 0.9 | Else |
| 72112 | 21 | 1 | Else |
| 73099 | 20 | 1 | Else |
| 73112 | 20 | 1 | Else |
| 74099 | 20 | 1 | Else |
| 74112 | 20 | 1 | Else |
| 75097 | 153 | 1 | Else |
| 75098 | 152 | 1 | Else |
| 75112 | 19 | 1 | Else |
| 76099 | 18 | 1 | Else |
| 76112 | 18 | 1 | Else |
| 77099 | 18 | 1 | Else |
| 77112 | 18 | 1 | Else |
| 78099 | 17 | 1 | Else |
| 78113 | 17 | 1 | Else |
| 78114 | 144 | 1 | Else |
| 78115 | 145 | 1 | Else |
| 78116 | 146 | 1 | Else |
| 78117 | 147 | 1 | Else |
| 78118 | 148 | 1 | Else |
| 78119 | 149 | 1 | Else |
| 78120 | 150 | 1 | Else |
| 79099 | 17 | 1 | Else |
| 79114 | 144 | 1 | Else |
| 79115 | 145 | 1 | Else |
| 79116 | 146 | 1 | Else |
| 79117 | 147 | 1 | Else |
| 79119 | 149 | 1 | Else |
| 79120 | 150 | 1 | Else |
| 80099 | 16 | 1 | Else |
| 80113 | 16 | 1 | Else |
| 80118 | 151 | 1 | Else |
| 81099 | 16 | 1 | Else |
| 81112 | 16 | 1 | Else |
| 81113 | 16 | 1 | Else |
| 82099 | 15 | 1 | Else |
| 82111 | 15 | 1 | Else |
| 83099 | 14 | 1 | Else |
| 83112 | 14 | 1 | Else |
| 83113 | 140 | 1 | Else |
| 83114 | 141 | 1 | Else |
| 83115 | 142 | 1 | Else |
| 83116 | 143 | 1 | Else |
| 84098 | 14 | 1 | Else |
| 84112 | 14 | 1 | Else |
| 85095 | 139 | 1 | Else |
| 85096 | 138 | 1 | Else |
| 85097 | 137 | 1 | Else |
| 85113 | 132 | 1 | Else |
| 85114 | 133 | 1 | Else |
| 85115 | 134 | 1 | Else |
| 85116 | 135 | 1 | Else |
| 85117 | 136 | 1 | Else |
| 86097 | 137 | 1 | Else |
| 86098 | 13 | 1 | Else |
| 86112 | 13 | 1 | Else |
| 87099 | 12 | 1 | Else |
| 87112 | 12 | 1 | Else |
| 88098 | 129 | 1 | Else |
| 88113 | 11 | 1 | Else |
| 89096 | 131 | 1 | Else |
| 89097 | 130 | 1 | Else |
| 89098 | 129 | 1 | Else |
| 89099 | 11 | 1 | Else |
| 89100 | 11 | 1 | Else |
| 89113 | 11 | 1 | Else |
| 90101 | 10 | 1 | Else |
| 90113 | 10 | 1 | Else |
| 91101 | 10 | 1 | Else |
| 91113 | 10 | 1 | Else |
| 92100 | 9 | 1 | Else |
| 92113 | 9 | 1 | Else |
| 93100 | 9 | 1 | Else |
| 93113 | 9 | 1 | Else |
| 94100 | 8 | 1 | Else |
| 94113 | 8 | 1 | Else |

| CH3D | DH | DH Fraction | PCB Code |
|---|---|---|---|
| 95101 | 8 | 1 | Else |
| 95112 | 8 | 1 | Else |
| 95113 | 8 | 1 | Else |
| 96101 | 7 | 1 | Else |
| 96111 | 7 | 1 | Else |
| 97097 | 128 | 1 | Else |
| 97100 | 7 | 1 | Else |
| 97111 | 7 | 1 | Else |
| 98095 | 125 | 1 | Else |
| 98096 | 124 | 1 | Else |
| 98098 | 122 | 1 | Else |
| 98099 | 121 | 1 | Else |
| 98112 | 6 | 1 | Else |
| 98114 | 118 | 1 | Else |
| 99097 | 123 | 1 | Else |
| 99098 | 122 | 1 | Else |
| 99099 | 121 | 1 | Else |
| 99112 | 6 | 1 | Else |
| 99114 | 117 | 1 | Else |
| 100097 | 126 | 1 | Else |
| 100100 | 5 | 1 | Else |
| 100112 | 5 | 1 | Else |
| 100114 | 116 | 1 | Else |
| 101097 | 127 | 1 | Else |
| 101100 | 5 | 1 | Else |
| 101112 | 5 | 1 | Else |
| 101114 | 115 | 1 | Else |
| 101117 | 119 | 1 | Else |
| 102100 | 4 | 1 | Else |
| 102113 | 4 | 1 | Else |
| 102115 | 105 | 1 | Else |
| 102116 | 106 | 1 | Else |
| 102117 | 107 | 1 | Else |
| 103098 | 103 | 1 | Else |
| 103099 | 102 | 1 | Else |
| 103118 | 108 | 1 | Else |
| 104100 | 4 | 1 | Else |
| 104114 | 104 | 1 | Else |
| 104115 | 105 | 1 | Else |
| 104116 | 106 | 1 | Else |
| 104117 | 107 | 1 | Else |
| 104119 | 109 | 1 | Else |
| 104120 | 110 | 1 | Else |
| 104121 | 111 | 1 | Else |
| 104122 | 112 | 1 | Else |
| 104123 | 113 | 1 | Else |
| 104124 | 114 | 1 | Else |
| 105100 | 3 | 1 | Else |
| 105113 | 3 | 1 | Else |
| 105118 | 120 | 1 | Else |
| 106100 | 3 | 1 | Else |
| 106114 | 98 | 1 | Else |
| 106115 | 99 | 1 | Else |
| 106116 | 100 | 1 | Else |
| 107100 | 3 | 1 | Else |
| 107113 | 3 | 1 | Else |
| 107115 | 101 | 1 | Else |
| 108100 | 252 | 0.1 | Else |
| 108100 | 253 | 0.3 | Else |
| 108100 | 254 | 0.6 | Else |
| 108113 | 2 | 1 | Else |
| 109100 | 2 | 1 | Else |
| 109113 | 2 | 1 | Else |
| 110100 | 2 | 1 | Else |
| 110113 | 2 | 1 | Else |
| 111100 | 1 | 1 | Else |
| 111112 | 1 | 1 | Else |
| 112100 | 1 | 1 | Else |
| 112112 | 1 | 1 | Else |
| 113100 | 1 | 1 | Else |
| 113112 | 1 | 1 | Else |

Table 9. Final input file structure for tributary, direct drainage, and total watershed loads.

| Field Name | Description |
|---|---|
| DH | POTPCB model DynHyd cell designation |
| year | |
| month | |
| day | |
| DDflow_liter/day | DD flow quantity (liters/day) |
| DDrefc_g/day | DD refractory carbon load (g/day) |
| DDbodc_g/day | DD particulate carbon load (g/day) |
| DDalgc_g/day | DD algal carbon load (g/day) |
| DDTOC_g/day | DD total organic carbon load (g/day) |
| DDTSS_g/day | DD total suspended solids load (g/day) |
| DD3-10PCB_g/day | DD PCB_3-10 load (g/day) |
| Tflow_liter/day | Trib flow quantity (liters/day) |
| Trefc_g/day | Trib refractory carbon load (g/day) |
| Tbodc_g/day | Trib particulate carbon load (g/day) |
| Talgc_g/day | Trib algal carbon load (g/day) |
| TTOC_g/day | Trib total organic carbon load (g/day) |
| TTSS_g/day | Trib total suspended solids load (g/day) |
| T3-10PCB_g/day | Trib PCB_3-10 load (g/day) |
| Totflow_liter/day | Sum of Tflow_liter/day and DDflow_liter/day |
| Totrefc_g/day | Sum of Trefc_g/day and DDrefc_g/day |
| Totbodc_g/day | Sum of Tbodc_g/day and DDbodc_g/day |
| Totalgc_g/day | Sum of Talgc_g/day and DDalgc_g/day |
| TotTOC_g/day | Sum of TTOC_g/day and DDTOC_g/day |
| TotTSS_g/day | Sum of TTSS_g/day and DDTSS_g/day |
| Tot3-10PCB_g/day | Sum of T3-10PCB_g/day and DD3-10PCB_g/day |

Table 10. 1994-2004 Average annual carbon load and yield for tributaries and Direct Drain Areas (Estimated based on WM5 model run November, 2006).

| Trib Name | TOC load, kg/year | TOC yield, kg/acre per year | refc, kg/yr | refc, kg/acre per year | bodc, kg/yr | bodc, kg/acre per year | algc, kg/yr | algc, kg/acre per year |
|---|---|---|---|---|---|---|---|---|
| Potomac R. | 33,400,636 | 4.5 | 17,363,957 | 2.3 | 10,724,859 | 1.4 | 5,311,820 | 0.72 |
| Rock Cr | 237,852 | 5.3 | 98,912 | 2.2 | 128,261 | 2.9 | 10,678 | 0.24 |
| Anacostia | 301,375 | 3.7 | 70,664 | 0.9 | 217,955 | 2.7 | 12,757 | 0.16 |
| Piscataway | 167,319 | 6.8 | 121,381 | 4.9 | 43,481 | 1.8 | 2,458 | 0.10 |
| Mattawoman | 217,859 | 6.2 | 165,739 | 4.7 | 48,493 | 1.4 | 3,627 | 0.10 |
| Nanjemoy | 62,181 | 6.5 | 53,440 | 5.6 | 5,837 | 0.6 | 2,904 | 0.30 |
| Wicomico | 211,922 | 7.9 | 157,330 | 5.8 | 46,329 | 1.7 | 8,264 | 0.31 |
| Zekiah Swamp+trib | 410,849 | 6.3 | 315,405 | 4.9 | 77,698 | 1.2 | 17,746 | 0.27 |
| St Clements | 99,909 | 8.7 | 67,121 | 5.8 | 32,064 | 2.8 | 724 | 0.06 |
| Up McIntosh Run | 156,924 | 8.5 | 115,441 | 6.3 | 36,503 | 2.0 | 4,980 | 0.27 |
| St Marys Riv | 112,188 | 7.3 | 86,010 | 5.6 | 23,012 | 1.5 | 3,165 | 0.21 |
| Hunting Creek | 262,937 | 11.9 | 183,622 | 8.3 | 77,563 | 3.5 | 1,752 | 0.08 |
| Accotink | 300,208 | 9.3 | 203,083 | 6.3 | 94,180 | 2.9 | 2,945 | 0.09 |
| Occoquan | 1,794,088 | 7.9 | 1,287,610 | 5.7 | 75,935 | 0.3 | 430,542 | 1.90 |
| Quantico | 93,855 | 5.4 | 82,402 | 4.8 | 7,371 | 0.4 | 4,082 | 0.24 |
| Aquia | 472,927 | 14.6 | 436,219 | 13.5 | 31,233 | 1.0 | 5,475 | 0.17 |
| All tribs exc Pot. | 4,902,393 | 7.4 | 3,444,379 | 5.2 | 945,915 | 1.4 | 512,099 | 0.77 |
| All Direct Drain | 9,941,219 | 11.9 | 8,713,067 | 10.5 | 1,228,152 | 1.5 | 0 | 0.0 |

**Table 11. $PCB_{3\text{-}10}$ concentrations and annual $PCB_{3\text{-}10}$ loads from WWTPs**

| Facility Name | NPDES | County | Flow, 2004 (MGD) | # samples | mean $PCB_{3\text{-}10}$ (ng/l) | 2004, gr/yr $PCB_{3\text{-}10}$ |
|---|---|---|---|---|---|---|
| Blue Plains | DC0021199 | District of Columbia | 334.24 | 4 | 1.569 | 724.0 |
| NSWC-Indian Head (2 Pipes) | MD0003158 | Charles | 0.21 | 0 | 0.240 | 0.1 |
| Indian Head | MD0020052 | Prince Georges | 0.25 | 0 | 0.240 | 0.1 |
| La Plata | MD0020524 | Charles | 1.17 | 0 | 0.240 | 0.4 |
| Beltsville USDA East* | MD0020842 | Prince Georges | 0.20 | 0 | 0.240 | 0.1 |
| Beltsville USDA West* | MD0020851 | Prince Georges | 0.09 | 0 | 0.240 | 0.0 |
| NSWC-Indian Head | MD0020885 | Charles | 0.42 | 2 | 3.841 | 2.3 |
| Piscataway | MD0021539 | Prince Georges | 22.08 | 2 | 0.125 | 3.8 |
| Mattawoman | MD0021865 | Charles | 8.12 | 3 | 0.125 | 1.4 |
| Leonardtown | MD0024767 | St Marys | 0.41 | 2 | 0.466 | 0.3 |
| NSWC-Dahlgren | VA0021067 | King George | 0.32 | 2 | 0.057 | 0.0 |
| Dale City #8 | VA0024678 | Prince William | 3.00 | 1 | 0.020 | 0.1 |
| Dale City #1 | VA0024724 | Prince William | 3.08 | 1 | 0.041 | 0.2 |
| UOSA* | VA0024988 | Fairfax | 27.20 | 1 | 0.002 | 0.1 |
| H.L. Mooney | VA0025101 | Prince William | 12.38 | 2 | 0.151 | 2.6 |
| Arlington | VA0025143 | Arlington | 28.39 | 2 | 0.477 | 18.7 |
| Alexandria | VA0025160 | Alexandria City | 37.42 | 3 | 0.353 | 18.2 |
| Noman Cole | VA0025364 | Fairfax | 41.89 | 7 | 0.411 | 23.8 |
| Colonial Beach | VA0026409 | Westmoreland | 0.89 | 1 | 2.458 | 3.0 |
| Dahlgren Sanitary District | VA0026514 | King George | 0.21 | 0 | 0.370 | 0.1 |
| Quantico-Mainside | VA0028363 | Prince William | 1.09 | 1 | 0.071 | 0.1 |
| Aquia | VA0060968 | Stafford | 4.39 | 1 | 0.081 | 0.5 |
| TOTAL | | | 527.46 | | | 799.9 |

**Table 12. BOD and PDC concentrations in WWTPs**

| FACILITY | NPDES | Avg BOD5 / CBOD5 (mg/l) | PDC (mg/l) | Source for BOD/CBOD |
|---|---|---|---|---|
| Blue Plains | DC0021199 | 2.37 | 1.66 | CBP database |
| NSWC-Indian Head | MD0003158 | 5.00 | 3.50 | CBP database |
| Indian Head | MD0020052 | 10.64 | 7.45 | CBP database |
| La Plata | MD0020524 | 5.34 | 3.74 | CBP database |
| NSWC-Indian Head | MD0020885 | 5.39 | 3.78 | CBP database |
| Piscataway | MD0021539 | 1.88 | 1.31 | CBP database |
| Mattawoman | MD0021865 | 7.15 | 5.00 | CBP database |
| Leonardtown | MD0024767 | 5.41 | 3.79 | CBP database |
| NSWC-dhlgren | VA0021067 | 1.10 | 0.77 | VADEQ |
| Dale City #8 | VA0024678 | 2.72 | 1.90 | EPA PCS website |
| Dale City #1 | VA0024724 | 2.61 | 1.83 | EPA PCS website |
| H.L. Mooney | VA0025101 | 2.57 | 1.80 | EPA PCS website |
| Arlington | VA0025143 | 2.20 | 1.54 | EPA PCS website |
| Alexandria | VA0025160 | 0.12 | 0.09 | EPA PCS website |
| Noman M. Cole | VA0025364 | 2.24 | 1.57 | EPA PCS website |
| Colonial Beach | VA0026409 | 3.81 | 2.66 | EPA PCS website |
| Dahlgren (Dahlgren Sanitary District) | VA0026514 | 4.95 | 3.47 | EPA PCS website |
| Quantico-Mainside | VA0028363 | 2.36 | 1.65 | EPA PCS website |
| Aquia | VA0060968 | 1.53 | 1.07 | EPA PCS website |
| Note: facilities located in tributary watersheds are not included. | | | | |

Table 13A. Contaminated sites contributing PCB loads to the POTPCB model.

| site_name | State | Lat | Long | tPCB_yr (gr/year) |
|---|---|---|---|---|
| Woodbridge-1+2 | VA | 38.64583 | -77.22958 | 1.24 |
| Davis | VA | 38.86530 | -77.04911 | 1.33 |
| CSX | VA | 38.80644 | -77.07918 | 0.76 |
| Quantico | VA | 38.51222 | -77.30000 | 1.10 |
| Dahlgren-17+19 | VA | 38.32347 | -77.02622 | 5.39 |
| Ft. Belvoir | VA | 38.68579 | -77.14056 | 9.49 |
| Kenilworth Landfill (South) | DC | 38.90333 | -76.95556 | 2.34 |
| Kenilworth Landfill (North) | DC | 38.90833 | -76.95028 | 0.61 |
| Rogers Electric | MD | 38.92000 | -76.91200 | 0.00 |
| Andrews Air Force Base | MD | 38.80600 | -76.89700 | 0.00 |
| Blossom Point Proving Ground (no remediation) | MD | 38.42000 | -77.09444 | 0.00 |
| Indian Head (no remediation at sub site) | MD | 38.59111 | -77.17417 | 0.10 |
| Substations (PEPCO 84) (remediated) | MD | 38.77444 | -76.95806 | 0.49 |
| Total annual PCB load (grams/year) | | | | 22.85 |

Table 13B. Contaminated sites in tributaries, tracked but not explicitly input to the POTPCB model

| site_name | State | Lat | Long | tPCB_yr (gr/year) |
|---|---|---|---|---|
| Atlantic | VA | 38.806548 | -77.166417 | 0.17 |
| United Rigging and Hauling | MD | 39.049167 | -76.893611 | 0.05 |
| Waldorf (Nike) | MD | 38.655000 | -76.856111 | 0.00 |
| White Oak | MD | 39.034000 | -76.986000 | 3.05 |
| Beltsville Agricultural Research Center | MD | 39.024000 | -76.924000 | 3.41 |
| Brandywine Receiver Station | MD | 38.666667 | -76.833333 | 0.00 |
| Brandywine DRMO | MD | 38.692000 | -76.839000 | 0.01 |
| St. Mary's Salvage | MD | 38.322222 | -76.555833 | 0.12 |
| Total annual PCB load (grams/year) | | | | 6.80 |

**Table 14. Annual net deposition of atmospheric PCB**

| Zone | surface area, km2 | PCB, gr/yr |
|---|---|---|
| regional | 1,020 | 1,632 |
| transition | 140 | 1,111 |
| urban | 24 | 388 |
| TOTAL | 1,184 | 3,131 |

**Table 15. Annual PCB loads to the tidal Potomac river by source category**.

| Source | annual PCB load, grams/year | % of total |
|---|---:|---:|
| Potomac River (Chain Bridge) | 9,330 | 42% |
| All other tributaries | 1,667 | 7% |
| Direct Drainage | 6,187 | 28% |
| Atmospheric Deposition (total PCB) | 3,131 | 14% |
| Combined Sewer Overflows | 1,148 | 5% |
| Waste Water Treatment Plants | 800 | 4% |
| Contaminated Sites (total PCB) | 23 | 0% |
| TOTAL | 22,286 | 100% |

Notes
- Loads are $PCB_{3-10}$ unless otherwise noted.
- Annual loads for Chain Bridge, other Tributaries, and Direct Drainage are highly variable depending on annual precipitation. Maximum annual may be several times higher than 1994-2005 average annual and minimum annual may be ½ to 1/3 the average annual.
- Waste Water Treatment Plant loads shown above do not include three facilities located within tributary watersheds (the two Beltsville USDA facilities and the UOSA facility). Annual load at these three facilities (total for all three) is estimated to be about 0.3 grams/year $PCB_{3-10}$.
- Contaminated Sites loads shown above do not include eight sites located within tributary watersheds. Annual load at these sites(total for all eight) is estimated to be about 7.8 grams/year total PCB.